

VERIFICATION

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[Title of the Invention] An image display apparatus

[Claims]

[Claim 1] An image display apparatus comprising:

- 5 (a) a luminous device composed of arrayed plural light sources;
- (b) an optical switch for inputting beams output from the luminous device and modulating the beams;
- (c) a parallel-conversion optical system for inputting one of beams output from the luminous device and beams modulated by the optical switch, and converting the
- 10 beams into substantially parallel beams; and
- (d) a display optical system for inputting one of beams output from the parallel-conversion optical system and beams modulated by the optical switch in order to display an image.

[Claim 2] The image display apparatus of claim 1, further comprising a beam-

15 conversion optical system between the parallel-conversion optical system and the optical switch, for converting a section size of the beams into a light-utilization size for the optical switch.

[Claim 3] The image display apparatus of claim 1 further comprising a plurality of luminous devices, parallel-conversion optical systems, and optical switches,

20 wherein the display optical system includes a combining optical system for combining beams modulated by the plurality of optical switches.

[Claim 4] The image display apparatus of claim 1, wherein the luminous device includes a semiconductor laser, as a light source, for generating a linear polarization to be utilized by the optical switch.

25 [Claim 5] The image display apparatus of claim 1, wherein the luminous device

includes arrayed integrated semiconductor lasers.

[Claim 6] The image display apparatus of claim 1, wherein the luminous device includes a surface-emitting semiconductor laser.

[Claim 7] The image display apparatus of claim 1, wherein the luminous device includes a light emitting diode as a light source.

[Claim 8] The image display apparatus of claim 1, wherein the luminous device includes a discharge lamp as a light source.

[Claim 9] The image display apparatus of claim 1, wherein the luminous device includes an electro-luminescence lamp as a light source.

[Claim 10] The image display apparatus of claim 1, wherein the optical switch is a liquid crystal panel.

[Claim 11] The image display apparatus of claim 1, wherein the optical switch is a polymer-dispersed liquid crystal panel.

[Claim 12] The image display apparatus of claim 1, wherein the optical switch is a reflection type liquid crystal panel.

[Claim 13] The image display apparatus of claim 1, further comprising a polarization-conversion system between the parallel-conversion optical system and the optical switch, for converting a beam polarization direction.

[Claim 14] The image display apparatus of claim 13, wherein the polarization-conversion system includes a polarization conversion element for converting a beam polarization direction corresponding with the light source.

[Claim 15] The image display apparatus of claim 13, wherein the luminous device and the polarization-conversion system are aggregated.

[Claim 16] The image display apparatus of claim 1, wherein the luminous device has plural light sources, an array shape of which is similar to a light-utilizing

shape of the optical switch.

[Claim 17] The image display apparatus of claim 1 further comprising a controller for controlling each of the plural light sources.

[Claim 18] The image display apparatus of claim 1, wherein the luminous device is an aggregation of light sources having different spectral distributions.

[Claim 19] The image display apparatus of claim 1, wherein the luminous device is an aggregation of discharge lamps, a gap length of each of which is less than 4mm, outputting parallel beam luminous flux of lumen equal to and more than several hundred, and the parallel-conversion optical system is an aggregation of reflectors making beams output from each of the discharge lamps be parallel beams.

[Claim 20] The image display apparatus of claim 1, wherein the luminous device is able to change at least one of a beam section shape and a beam section size.

[Claim 21] The image display apparatus of claim 1, wherein the luminous device is able to change a light source type.

[Claim 22] The image display apparatus of claim 1, wherein the luminous device is able to change an array shape of light source.

[Claim 23] The image display apparatus of claim 1, wherein the luminous device allocates light sources having different sizes.

[Claim 24] The image display apparatus of claim 1, wherein the luminous device includes a lamp in which a part of a discharge tube is used as a reflector.

[Claim 25] An image display apparatus comprising:

- (a) a light source for outputting a linear polarization;
- (b) optical switch for inputting the linear polarization output from the light source and modulating the linear polarization; and
- (c) a display optical system for displaying a beam modulated by the optical switch.

[Claim 26] The image display apparatus of claim 25, wherein the light source is a gas laser of outside mirror type including a Brewster's window.

[Claim 27] The image display apparatus of claim 25, wherein the light source is a white laser for emitting a white beam.

5 [Claim 28] The image display apparatus of claim 25, wherein the light source emits a light based on a superradiation.

[Claim 29] An image display apparatus comprising:

(a) a light source for color image;

(b) a light source for luminance image;

10 (c) an optical switch for color image for creating a color image by using the light source for color image;

(d) an optical switch for luminance image for creating a luminance image by using the light source for luminance image; and

(e) a combining optical system for combining the color image created by the optical switch for color image with the luminance image created by the optical switch for luminance image in order to create a combination image.

[Claim 30] The image display apparatus of claim 1, wherein the luminous device is composed of plural light sources arrayed on a curved surface.

[Claim 31] The image display apparatus of claim 30, wherein the curved surface has its curvature center on an optical axis of beams input into the optical switch.

[Claim 32] The image display apparatus of claim 31, wherein the curved surface is a concave surface.

[Claim 33] The image display apparatus of claim 31, wherein the curved surface is a convex surface.

25 [Claim 34] An image display apparatus comprising:

(a) a luminous device composed of arrayed light sources outputting different wavelength beams in time sharing.

[Claim 35] An image display apparatus comprising:

(a) a luminous device composed of arrayed light sources outputting different wavelength beams in time sharing, and

(b) an optical switch for inputting the different wavelength beams output from each of the arrayed light sources of the luminous device, and modulating input different wavelength beams in time sharing.

[Claim 36] The image display apparatus of claim 34 or 35, wherein the luminous device is composed of a plurality of luminous devices in which a plurality of semiconductor lasers outputting same wavelength beams is arrayed, and each of the plurality of luminous devices operates in time sharing in order to output a beam in time sharing.

[Claim 37] The image display apparatus of claim 34 or 35, wherein the luminous device is composed of arrayed semiconductor laser groups, each of which is made of semiconductor lasers of plural kinds outputting different wavelength beams.

[Claim 38] The image display apparatus of claim 37, wherein each of the semiconductor lasers of plural kinds operates in time sharing in order to output a beam in time sharing.

[Claim 39] The image display apparatus of claim 37, wherein the optical switch is a liquid crystal panel, and each of the arrayed semiconductor laser groups is provided to be corresponding to each pixel of the liquid crystal panel.

[Claim 40] The image display apparatus of claim 37, wherein the luminous device includes a surface-emitting semiconductor laser composed of arrayed semiconductor laser groups, each of which is made of semiconductor lasers of

plural kinds outputting different wavelength beams.

[Claim 41] The image display apparatus of claim 1, 34 or 35, further comprising a beam-conversion optical system for making a luminance distribution of beams output from the luminous device to be uniform.

5 [Claim 42] The image display apparatus of claim 41, wherein the beam-conversion optical system includes an analog phase control element for controlling a beam phase.

[Claim 43] The image display apparatus of claim 42, wherein the analog phase control element is a modified curve surface lens.

10

[Detailed Explanation of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an image display apparatus, especially to
15 the image display apparatus, such as a liquid crystal projector, applying a liquid crystal panel.

[0002]

[Related Art]

As a conventional image display apparatus, a polarization illumination
20 apparatus is disclosed in Unexamined Japanese Patent Publication No. 8-304739. The conventional image display apparatus will now be explained with reference to the drawings and the statements described in the Unexamined Japanese Patent Publication No. 8-304739.

Fig. 28 shows a schematic plan view of summary configuration of the
25 conventional polarization illumination apparatus. The polarization illumination

apparatus 1 is mostly composed of a light source part 2, a first lens plate 3 and a second lens plate 4 which are arranged along the system optical axis L. Output beams from the light source part 2 are converged to the inside of the second lens plate 4 through the first lens plate 3. While the beams are passing through the second lens plate 4, random polarization beams are converted into polarization beams of one kind having the same polarization direction, to reach a luminous range 5.

[0003]

The light source part 2 is mainly composed of a light source lamp 201 and a parabolic reflector 202. Random polarization beams emitted from the light source lamp 201 are reflected in one direction by the parabolic reflector 202 to be almost parallel luminous flux input into the first lens plate 3. It is acceptable to use an elliptical reflector or a spherical reflector and such instead of the parabolic reflector 202. The light source optical axis R is inclined by a specific angle with respect to the system optical axis L.

[0004]

Fig. 29 shows an outward view of the first lens plate 3. As shown in Fig. 29, the first lens plate 3 is composed of plural micro rectangle collective lenses 301 arranged lengthwise and crosswise. Beams input to the first lens plate 3 form collective images, whose number is the same as the number of the rectangle collective lenses 301, on the plane perpendicular to the system optical axis L, by the collecting function of the rectangle collective lenses 301. These plural collective images will now be called as a secondary light source image because the plural collective images indicate just the projection image of the light source lamp.

[0005]

With reference to Fig. 28 again, the second lens plate 4 is going to be explained. The second lens plate 4 is a compound layered composition of a collective lens array 410, a polarization separation prism array 420, a $\lambda/2$ phase-retardation plate 430 and an output side lens 440. The second lens plate 4 is located in the perpendicular plane to the system optical axis L, adjacent to the position of the secondary light source image formed by the first lens plate 3. The second lens plate 4 has functions of a second lens plate of integrator optical system, the polarization separation element, and a polarization-conversion element.

[0006]

The collective lens array 410 has a configuration similar to the first lens plate 3. The collective lens array 410 is composed of arrayed plural collective lenses 411 whose number is the same as the number of the rectangle collective lenses 301 of the first lens plate 3. The collective lens array 410 has a function of converging beams from the first lens plate 3. The collective lens 410 corresponds to the second lens plate of the integrator optical system.

[0007]

It is not necessary for the collective lens 411 of the collective lens array 410 and the rectangle collective lens 301 of the first lens plate 3 to have the same size and shape, and the same lens characteristics. It is desirable for the collective lens array 410 and the rectangle collective lens 310 to be optimized depending upon the beam characteristics from the light source part 2. Anyhow, it is ideal for the principal ray of incident light into the polarization separation prism array 420 to be parallel to the system optical axis L. Considering this respect, most collective lenses 411 have the same lens characteristic as that of the rectangle collective lens 301 composing the first lens plate 3, or most collective lenses 411

having a similar shape to the rectangle collective lens 301 and the same lens characteristic as the rectangle collective lens 301 are used.

[0008]

Fig. 30 shows an outward view of the polarization separation prism array 420.

5 As shown in Fig. 30, the polarization separation prism 420 is composed of base units made by a pair of a polarization beam splitter 421 and a reflecting mirror 422. The polarization beam splitter 421 is composed of a quadrangular prism aggregation which includes a polarization separation film inside. The reflecting mirror 422 is also composed of a quadrangular prism aggregation which includes a reflection film inside. The polarization separation prism array 420 is composed of the pairs arranged in a plane, meaning the plane where the secondary light source image is formed. Each pair, the base unit is regularly arranged to be corresponding to each collective lens 411 of the collective lens array 410. The breath W_p of the polarization beam splitter 421 is equal to the breath W_m of the reflecting mirror 422. In the present case, the value of the breath W_p or W_m is specified to be a half of the breath of the collective lens 411 composing the collective lens array 410, but it is not restricted to be the half.

[0009]

The second lens plate 4 including the polarization separation prism array 420 is positioned so that the secondary light source image formed by the first lens plate 3 can be located at the place of the polarization beam splitter 421. Therefore, the light source 2 is located so that the light source optical axis R of the light source 2 may slightly incline with respect to the system optical axis L .

[0010]

25 Referring to Figs. 28 and 30, the random polarization beam will now be

explained. The random polarization beam input into the polarization separation prism array 420 is separated into two polarization beams, a polarization beam P and a polarization beam S, having different polarization directions, by the polarization beam splitter 421. The polarization beam P passes through the polarization beam splitter 421 without changing its advancing direction. On the other hand, since the polarization beam S is reflected at a polarization separation film 423 of the polarization beam splitter 421, the advancing direction of the polarization beam S is changed by around 90 degrees. Then, the polarization beam S is reflected at a reflecting surface 424 of adjacent reflecting mirror 422 (the reflecting mirror for making a pair with the polarization beam splitter), the advancing direction of the polarization beam S is changed by around 90 degrees. Finally, the polarization beam S is output from the polarization separation prism array 420, being almost parallel to the polarization beam P.

[0011]

The $\lambda/2$ phase-retardation plate 430, in which a $\lambda/2$ phase-retardation film 431 is regularly arranged, is provided on the outputting surface of the polarization separation prism array 420. Namely, the $\lambda/2$ phase-retardation film 431 is arranged only on the outputting surface of the polarization beam splitter 421 composing the polarization separation prism array 420, and the $\lambda/2$ phase-retardation film 431 is not arranged on the outputting surface of the reflecting mirror 422. Accordingly, when the polarization beam P output from the polarization beam splitter 421 passes through the $\lambda/2$ phase-retardation film 431, the polarization beam P receives the rotating function of the polarization surface, to be converted into the polarization beam S. On the other hand, since the polarization beam S output from the reflecting mirror 422 does not pass through

the $\lambda/2$ phase-retardation film 431, the polarization beam S does not receive the rotating function of the polarization surface. The polarization beam S, not being changed, passes through the $\lambda/2$ phase-retardation plate 430.

To sum up the above, the random polarization beams are converted into the polarization beams of one kind (in this case, the polarization beam S), by the polarization separation prism array 420 and the $\lambda/2$ phase-retardation plate 430.

[0012]

As set forth the above, the luminous flux having been converted into the polarization beams S is output from the output side lens 440 to go to the luminous range 5 and overlapped to be an image on the luminous range 5. Namely, the image sent from the first lens plate 3 is overlapped to be an image on the luminous range 5, through the second lens plate 4. Simultaneously, the random polarization beams are spatially separated into the polarization beams of two kinds having different polarization directions, by the polarization separation prism array 420 located in-between. Then, the polarization beams of two kinds are converted into the polarization beams of one kind through the $\lambda/2$ phase-retardation plate 430. Namely, almost all the random beams are sent to the luminous range 5. Accordingly, the luminous range 5 is uniformly illuminated by the polarization beams of almost one kind.

[0013]

Fig. 31 shows an example of the projection type display apparatus applying the polarization illumination apparatus 1 of Fig. 28. The polarization illumination apparatus 1 of a projection type display apparatus 3400 of Fig. 31 includes the light source part 2 for outputting random polarization beams in the position direction. The random polarization beams emitted from the light source

part 2 are led to a specific position on the second lens plate 4, being converged by the first lens plate 3. Then, the random polarization beams are separated into the polarization beams of two kinds, by polarization separation prism array 420 in the second lens plate 4. The polarization beam P out of the separated polarization beams is converted into the polarization beam S by the $\lambda/2$ phase-retardation plate 430.

[0014]

A red beam out of the luminous flux output from the polarization illumination apparatus 100 is transmitted through a blue and green reflecting dichroic mirror 3401, and a blue beam and a green beam are reflected at it. Then, the red beam is reflected at a reflecting mirror 3402, to go to a first liquid crystal light bulb 3403. The green beam out of the above blue beam and green beam is reflected at a green reflecting dichroic mirror 3404, to go to a second liquid crystal light bulb 3405.

[0015]

Since the blue beam has the longest optical path of all the colors, light leading means 3450 composed of an input side lens 3406, a relay lens 3408, and an output side lens 3410 is provided for the blue beam. After passing through the green reflecting dichroic mirror 3404, the blue beam is led to the relay lens 3408 via the input side lens 3406 and a reflecting mirror 3407. After being converged on the relay lens 3408, the blue beam is led to the output side lens 3410 by a reflecting mirror 3409. Then, after all, the blue beam reaches a third liquid crystal light bulb 3411. The liquid crystal bulbs 3403, 3405, and 3411 respectively modulate each color. After image information corresponding to each color being applied, the modulated color is input to a dichroic prism 3413 (color combining means). On the dichroic prism 3413, a dielectric multi-layered film

reflecting red and a dielectric multi-layered film reflecting blue are formed like a cross, and each modulated luminous flux is combined. The combined luminous flux passes through a projection lens 3414 (projection means) and forms an image on a screen 3415. What has been described above is the conventional apparatus disclosed in Unexamined Japanese Patent Publication No. 8-304739.

[0016]

Now, the light source will be described. Being bright is important in the projection type liquid crystal projector. In order to realize the brightness, a bright light source is needed. Then, so as to obtain enough brightness from the light source, the size of the light source needs to be large. In order to obtain the enough brightness, according to the Laws of Stephen Boltzmann and Wien, it is impossible to make the light source size be less than a specific size. Besides, considering the life time of light source or the color temperature of light source, it is impossible to make the light source size be less than the specific size. When a long life time is required, it is inevitably necessary for the light source to have a specific length.

Fig. 32 shows characteristics of various light sources. In the case of the metal halide lamp having an appropriate color temperature, when a long time life of thousands of hours is required, the arc length, meaning the optical path length, based on the length (gap length) between the discharge electrodes is 5mm. Fig. 33 shows a space distribution of emission luminance of 250W whose arc length is 5mm. In Fig. 33, the brightest emission luminance is defined to be 1.0 and values less than or equal to 1.0 is a weighted value based on the 1.0.

[0017]

Fig. 34 shows a metal halide lamp of 250W used in the conventional liquid

crystal projector. The metal halide lamp is composed of a lamp 10 and a main reflecting mirror 11. For instance, the main reflecting mirror 11 is composed of a rotating parabolic mirror. The main reflecting mirror 11 includes a filter 14 for cutting a band of beams, such as infrared rays outside of red, which causes unnecessary heat for the optical system. The infrared heats the main reflecting mirror and so on. In order to deal with (cool) the heat, the main reflecting mirror needs to be a specific size. The diameter D_m of main reflecting mirror of the lamp shown in Fig. 34 is 80mm (8cm). In the projection type liquid crystal projector, it is needed to make the beams be parallel illumination beams as much as possible.

Beams emitted from the place at the focal point of the main reflecting mirror 11 composed of the rotating parabolic surface of Fig. 34 are parallel to the optical axis, while beams emitted from other place except the focal point are not parallel to the optical axis and incline to the optical axis. Supposing that the maximum value of the inclining is $d\theta$ (not shown), the inclination maximum value $d\theta$ is in proportion to the arc length l_s located on the optical axis and in inverse proportion to the main reflecting mirror diameter D_m and the main reflecting mirror aspect ratio asr .

[0018]

The aspect ratio asr is expressed by a value of "main reflecting mirror diameter D_m /main reflecting mirror length L_m ". In the conventional lamp, as shown in Fig. 34, since the front end of the main reflecting mirror is placed ahead of the light source position in order to enhance the light collecting efficiency, so that the aspect ratio is around 2. As long as the arc length l_s has a specific length, it is necessary for the main reflecting mirror diameter D_m to be long to some extent, in order to make the inclination maximum value $d\theta$ be within the

light incident permission range of the dichroic mirror or the thin film element, such as the polarization separation element. For instance, if the light incident permission range of the dichroic mirror or the thin film element, such as the polarization separation element, is supposed to be 6 degrees, in the case of the light source whose arc length is 5mm and the conventional main reflecting mirror whose aspect ratio is equal to or less than 2 being used, it is impossible to set the main reflecting mirror diameter to be equal to or less than 7.5cm (3 inches).

[0019]

It is ideal to use a point light source whose arc length is as short as possible in order to obtain parallel beams. However, if the light source is set to largely output for the purpose of obtaining the high luminance, the arc length needs to be long, so that it is difficult to obtain parallel beams. In order to input lights into a liquid crystal panel whose diagonal length is 1.3 inches, the lamp arc length needs to be equal to or less than 4mm. If the arc length is more than this value, since the light-utilizing efficiency is decreased even when the light source high outputting is planned, a large liquid crystal panel is needed, which causes the high cost. When a metal halide lamp of 400W (arc length 4mm) is used for the liquid crystal panel of 1.3 inches, the projector luminance is equal to or less than 2000lm. Even when a metal halide lamp of 500W (arc length 5mm) is used, it does not exceed 2000lm since the arc length is 5mm. Besides, the life time of high output discharge lamp becomes short when the arc length is shortened. Accordingly, it has been very difficult to technically solve the above problems.

[0020]

Fig. 35 illustrates a light shading. Parallel beams can be projected on the liquid crystal panel to be utilized regardless of the length, short or long, of the

optical path. However, regarding a beam A and a beam B, whether they can be utilized or not is dependent on the optical path length. In the case of an optical path A whose optical path length is short, both the beams A and B can be utilized. In the case of an optical path B whose optical path length is long, only up to the beam B can be utilized but the beam A can not be utilized. Accordingly, it is necessary to make the optical path length be short as little as possible, in order to effectively utilize the light.

[0021]

Fig. 36 illustrates the light-utilizing rate. C shows a section of the beam emitted from the main reflecting mirror 11. D indicates a beam part projected onto the liquid crystal panel, that is the part to be utilized, out of the beam emitted from the main reflecting mirror 11. Since the section of the beam from the main reflecting mirror 11 is circle and the liquid crystal panel is square, the circumferential beam can not be utilized. Consequently, beam being equal to or more than 30 percent out of the beam emitted from the main reflecting mirror 11 can not be utilized.

[0022]

Fig. 43 shows a configuration of the conventional three color image projector, disclosed in Japanese Unexamined Patent Publication No. 6-511328 for PCT Application, respectively applying monochrome laser light sources LR, LG, and LB for each of the primary colors of red, green and blue. Referring to the description in the Publication, the configuration of Fig. 43 will now be explained.

The laser light source LR emits a polarization monochrome beam FMR corresponding to the primary color red. The red monochrome beam goes in the direction of a focal lens LFR along an axis 24. This operation brings about the

convergence and divergence. Then, after going enough distance to make the red beam FMR be large for projecting the modulation screen, the red beam goes through an adaptive lens LAR to be parallel beams. The red beam goes to a visual field lens LC to form a red monochrome image. Further, for instance, the red beam goes to the liquid crystal matrix screen (LCD). After passing through an analyzer A, the red beam goes into a dichroic cube CD. This dichroic cube includes a dichroic mirror MD1 being sensitive to red. By this dichroic mirror MD1, the red beam is bent to be on a projection axis 25 being perpendicular to the propagation axis 24.

The laser light source LB emits a polarization monochrome beam FMB corresponding to the primary color blue. The blue monochrome beam FMB goes in the direction of the dichroic cube CD along the axis 24, meaning the blue monochrome beam goes in the opposite direction of the red beam FMR. Then, the blue beam FMB passes through a focal lens LFB, an adaptive lens LAB, the visual field lens LC, a modulation screen EB1 and the analyzer A in order. Namely, these operations of the blue beam FMB are the same as operations performed by a corresponding element for the red beam FMR. The blue beam FMB goes into the dichroic cube CD to reach a second dichroic mirror MD2 being sensitive to blue. By the conventional method, since the two dichroic mirrors compose planes being perpendicular each other, the blue beam FMB is reflected to be on the projection axis 25.

The laser light source LG emits a polarization monochrome beam FMG corresponding to the primary color green. The green monochrome beam FMG goes in the direction of the dichroic cube CD along the projection axis 25. Then, the green beam FMG passes through a focal lens LFG, an adaptive lens LAG, a

modulation screen EG1 and the analyzer A in order. These operations are the same as operations performed by the corresponding elements for the beams FMR and FMB. The green beam FMG passes through the dichroic cube CD without reflecting, in the direction of a projection objective lens OP along the projection axis 25, with the red beam FMR and the blue beam FMB. The three beams FMR, FMB, and FMG respectively carrying a monochrome image are projected on a projection screen EP. As set forth above, the conventional apparatus disclosed in Japanese Unexamined Patent Publication No. 6-511328 for PCT Application has been explained.

10 [0023]

[Problems to be solved by the Invention]

Regarding the conventional image display apparatus, it is possible to enhance the light-utilizing rate because the polarization-conversion optical system is provided. However, it has a problem of the apparatus configuration being complicated. Besides, a problem of the luminous device being large-sized exists in the conventional image display apparatus. Since the arc length of the conventional luminous device is long, it is impossible to generate parallel beams because the luminous device can not be treated as a point light source. As the arc length is long, a part whose emission luminance is not uniform is generated, which causes a problem of generating unevenness or change in a displayed image. In the conventional image display apparatus, only a part of circle beams emitted from the luminous device is projected onto the liquid crystal panel, which causes a light-utilizing rate deterioration. Furthermore, since one laser light source is respectively used for red, green, and blue in the conventional image display apparatus applying the laser light source, it is difficult to generate an ample

amount of light. Only a part of circle beams emitted from one laser light source is projected onto the liquid crystal panel, which causes a light-utilizing rate deterioration.

[0024]

5 The present invention is contrived to solve the above problems. One of objects of the present invention is to provide an image display apparatus in which the polarization-conversion optical system is not necessary.

[0025]

10 Another object is to provide an image display apparatus which emits parallel beams and whose light-utilizing rate is enhanced.

[0026]

Another object is to provide an image display apparatus which is down-sized and whose image quality is enhanced.

[0027]

15 [Means for solving the Problems]

An image display apparatus according to the present invention comprises:

- (a) a luminous device composed of arrayed plural light sources;
- (b) an optical switch for inputting beams output from the luminous device and modulating the beams;
- 20 (c) a parallel-conversion optical system for inputting one of beams output from the luminous device and beams modulated by the optical switch, and converting the beams into substantially parallel beams; and
- (d) a display optical system for inputting one of beams output from the parallel-conversion optical system and beams modulated by the optical switch in order to
- 25 display an image.

[0028]

The image display apparatus further comprises a beam-conversion optical system between the parallel-conversion optical system and the optical switch, for converting a section size of the beams into a light-utilization size for the optical switch.

[0029]

The image display apparatus further comprises a plurality of luminous devices, parallel-conversion optical systems, and optical switches, wherein the display optical system includes a combining optical system for combining beams modulated by the plurality of optical switches.

[0030]

The luminous device includes a semiconductor laser, as a light source, for generating a linear polarization to be utilized by the optical switch.

[0031]

The luminous device includes arrayed integrated semiconductor lasers.

[0032]

The luminous device includes a surface-emitting semiconductor laser.

[0033]

The luminous device includes a light emitting diode as a light source.

[0034]

The luminous device includes a discharge lamp as a light source.

[0035]

The luminous device includes an electro-luminescence lamp as a light source.

[0036]

The optical switch is a liquid crystal panel.

[0037]

The optical switch is a polymer-dispersed liquid crystal panel.

[0038]

The optical switch is a reflection type liquid crystal panel.

5 [0039]

The image display apparatus further comprises a polarization-conversion system between the parallel-conversion optical system and the optical switch, for converting a beam polarization direction.

[0040]

10 The polarization-conversion system includes a polarization conversion element for converting a beam polarization direction corresponding with the light source.

[0041]

The luminous device and the polarization-conversion system are aggregated.

15 [0042]

The luminous device has plural light sources, an array shape of which is similar to a light-utilizing shape of the optical switch.

[0043]

20 The image display apparatus further comprises a controller for controlling each of the plural light sources.

[0044]

The luminous device is an aggregation of light sources having different spectral distributions.

[0045]

25 The luminous device is an aggregation of discharge lamps, a gap length of

each of which is less than 4mm, outputting parallel beam luminous flux of lumen equal to and more than several hundred, and the parallel-conversion optical system is an aggregation of reflectors making beams output from each of the discharge lamps be parallel beams.

5 [0046]

The luminous device is able to change at least one of a beam section shape and a beam section size.

[0047]

The luminous device is able to change a light source type.

10 [0048]

The luminous device is able to change an array shape of light source.

[0049]

The luminous device allocates light sources having different sizes.

[0050]

15 The luminous device includes a lamp in which a part of a discharge tube is used as a reflector.

[0051]

An image display apparatus according to the present invention comprises:

(a) a light source for outputting a linear polarization;

20 (b) optical switch for inputting the linear polarization output from the light source and modulating the linear polarization; and

(c) a display optical system for displaying a beam modulated by the optical switch.

[0052]

The light source is a gas laser of outside mirror type including a Brewster's
25 window.

[0053]

The light source is a white laser for emitting a white beam.

[0054]

The light source emits a light based on a superradiation.

5 [0055]

An image display apparatus according to the present invention comprises:

(a) a light source for color image;

(b) a light source for luminance image;

(c) an optical switch for color image for creating a color image by using the light
10 source for color image;

(d) an optical switch for luminance image for creating a luminance image by using
the light source for luminance image; and

(e) a combining optical system for combining the color image created by the optical
switch for color image with the luminance image created by the optical switch for
15 luminance image in order to create a combination image.

[0056]

The luminous device is composed of plural light sources arrayed on a curved
surface.

[0057]

20 The curved surface has its curvature center on an optical axis of beams input
into the optical switch.

[0058]

The curved surface is a concave surface.

[0059]

25 The curved surface is a convex surface.

[0060]

An image display apparatus according to the present invention comprises:

(a) a luminous device composed of arrayed light sources outputting different wavelength beams in time sharing.

5 [0061]

An image display apparatus according to the present invention comprises:

(a) a luminous device composed of arrayed light sources outputting different wavelength beams in time sharing, and

(b) an optical switch for inputting the different wavelength beams output from
10 each of the arrayed light sources of the luminous device, and modulating input different wavelength beams in time sharing.

[0062]

The luminous device is composed of a plurality of luminous devices in which a plurality of semiconductor lasers outputting same wavelength beams is arrayed,
15 and each of the plurality of luminous devices operates in time sharing in order to output a beam in time sharing.

[0063]

The luminous device is composed of arrayed semiconductor laser groups, each of which is made of semiconductor lasers of plural kinds outputting different
20 wavelength beams.

[0064]

Each of the semiconductor lasers of plural kinds operates in time sharing in order to output a beam in time sharing.

[0065]

25 The optical switch is a liquid crystal panel, and each of the arrayed

semiconductor laser groups is provided to be corresponding to each pixel of the liquid crystal panel.

[0066]

The luminous device includes a surface-emitting semiconductor laser
5 composed of arrayed semiconductor laser groups, each of which is made of semiconductor lasers of plural kinds outputting different wavelength beams.

[0067]

The image display apparatus further comprises a beam conversion optical
system for making a luminance distribution of beams output from the luminous
10 device to be uniform.

[0068]

The beam-conversion optical system includes an analog phase control
element for controlling a beam phase.

[0069]

15 The analog phase control element is a modified curve surface lens.

[0070]

[Embodiments]

Embodiment 1.

Fig. 1 shows a liquid crystal projector employing transmission type liquid
20 crystal panels, as an example of image display apparatus according to the present invention. The liquid crystal projector is composed of a luminous device 50, a parallel-conversion optical system 60, an optical switch 70, and a display optical system 80. The luminous device 50 is composed of an LD (laser diode) array 51 emitting red, an LD array 52 emitting green, and an LD array 53 emitting blue.
25 The parallel-conversion optical system 60 is composed of a lens array 61, a lens

array 62, and a lens array 63. The optical switch 70 is composed of a red-transmission type liquid crystal panel 71, a green-transmission type liquid crystal panel 72 and a blue-transmission type liquid crystal panel 73. The display optical system 80 is composed of a combining optical system 90, a projection lens 95 and a screen 96. The combining optical system 90 is composed of a cross dichroic prism 91 (or cross dichroic mirror). The cross dichroic prism 91 is used in Fig. 1, which leads the advantage that lengths of R, G, and B rays are equivalent.

[0071]

Fig. 2 shows the LD array 51 and the lens array 61. Fig. 3 shows a front view of the LD array 51. The LD array 51 as shown in Figs. 2 and 3 is composed of semiconductor lasers 54 of $M \times N$. Fig. 4 shows a configuration of the semiconductor laser 54. The LD array 51 of Fig. 3 is composed of the semiconductor lasers 54 of Fig. 4 being piled up lengthwise and crosswise and fixed by using a method such as bonding. As shown in Fig. 4, the semiconductor laser 54 has a double hetero-structure and is sometimes called a laser diode (LD).

As the laser diode (LD), GaN can be used for blue, ZnSe or the second harmonic (generation of half wave) of GaAsP (wavelength: approximately $1.10 \mu m$) can be used for green, and AlGaInP (wavelength: around 658 nm) can be used for red. The output beam from the semiconductor laser 54 is polarized in parallel to the hetero junction surface. Namely, a linearly polarized beam (a wave P or a wave S) is oscillated from the semiconductor laser 54. The polarization-conversion optical system which has been conventionally used is not needed by way of corresponding the direction of the linearly polarized beam output from the semiconductor laser to the direction of the linearly polarized beam utilized by each

of the liquid crystal panels 71, 72 and 73.

[0072]

The output beam from the semiconductor laser 54 diverges as shown in Fig. 4. Namely, the output beam from the semiconductor laser 54 is not a parallel beam. 5 The feature of the output beam can be obtained by measuring a far field pattern. The far field pattern as shown in Fig. 4 is known to distribute like the shape of a bell, being symmetrical with respect to the center axis, that is called Gaussian distribution. This far field pattern changes depending upon the distance from the semiconductor laser 54. The output beam from the semiconductor laser 54 10 can be converted to a parallel beam, by placing the lens array 61 to be corresponding with the feature of the far field pattern. Namely, parallel beams can be obtained by deciding the lens specification of the lens array 61 based on the distance between the LD array 51 and the lens array 61. As shown in Fig. 2, when the lens array 61 is located at the place where output beams from the 15 neighboring semiconductor lasers 54 just meet each other, parallel beams having a wholly uniform luminance distribution can be made.

[0073]

As stated above, since the output beams oscillated from the semiconductor lasers 54 are directly polarized beams which can be utilized by each of the liquid 20 crystal panels 71, 72 and 73, the polarization-conversion optical system conventionally used is not necessary. Accordingly, a liquid crystal projector having a very simple optical system configuration can be manufactured. Besides, the integrator optical system conventionally used also becomes unnecessary. Consequently, a display apparatus being small and low-cost can be realized.

25 Besides, since the luminous device 50 being the array, parallel beams having

the same shape or a similar shape to the liquid crystal panel are generated and all the generated beams are utilized, which enormously enhances the light-utilization rate.

As shown in Fig. 4, since the oscillation range is equal to or less than $2\mu\text{m}$ (micro meter), it can be almost regarded that the light source is a point light source. Accordingly, comparing with the conventional lighting equipment, it is possible to generate parallel beams closer to the perfect parallel than the conventional ones.

As the size of the resonator of the semiconductor laser 54 is $200\mu\text{m}$ through $300\mu\text{m}$ as shown in Fig. 4 and the reflecting mirror conventionally used is not installed, the whole size of the apparatus can be small. For instance, in the case of the liquid crystal panel whose size is around 1.3 inches being used, the diameter of the main reflecting mirror needs to be about 8 cm as set forth above. However, according to the present invention, it is enough to use the luminous device 50 whose diagonal length is 1.3 inches even when a beam of 1.3 inches diagonally long is directly generated by using the luminous device 50. Accordingly, the apparatus is enormously downsized.

[0074]

Fig. 5 shows the case of applying a beam-conversion optical system 65. The beam-conversion optical system is composed of convex lenses 66 and 67. When the size of the LD array 51 does not coincide with that of the red-transmission type liquid crystal panel 71, as shown in Fig. 5, the beam-conversion optical system 65 is set up between the lens array 61 and the red-transmission type liquid crystal panel 71 in order to convert the section size of parallel beams. If the red-transmission type liquid crystal panel 71 is larger than the LD array 51, though

not shown, the beam size is converted to be extended, by inverting the locations of the convex lens 66 and the convex lens 67 in Fig. 5. Accordingly, the LD array 51 can be smaller by setting up the beam-conversion optical system 65.

[0075]

5 Fig. 6 shows another example of the LD array 51. The LD array 51 is composed of semiconductor lasers 55 of N layers. The semiconductor laser 55 is a collection of laser diodes unified in a lateral row. The semiconductor laser 55 can be manufactured by using a semiconductor integrated circuit. It is also acceptable, though not shown, to manufacture the LD array 51 by using a
10 semiconductor integrated circuit.

[0076]

Fig. 7 shows a surface-emitting semiconductor laser 56. The surface-emitting semiconductor laser 56 is made of laser diodes generating output beams vertically with respect to the active layer as shown in Fig. 8. The resonator
15 length of the surface-emitting semiconductor laser 56 is around $1\ \mu\text{m}$ through $2\ \mu\text{m}$, whereas the resonator length of the semiconductor laser 54 shown in Fig. 4 is $200\ \mu\text{m}$ through $300\ \mu\text{m}$. Therefore, the size can be smaller. The output beams are circular beams. A laser array being high-dense and two-dimensional can be provided as shown in Fig. 8. As to the output beams from the surface-emitting
20 semiconductor laser 56, being linearly polarized beams, it is said to be difficult performing a fixed-direction polarization control for each of the beams. However, some cases succeeded in the polarization control by changing the surface direction of the substrate, applying quantum dots to the active layer, or installing a diffraction grating metal mirror, have been reported.

25 Namely as set forth, it is possible to control the polarization direction of

plural beams from the surface-emitting semiconductor laser 56 to be fixed. Then, an array can be formed with the surface-emitting semiconductor laser 56 to be the luminous device 50.

[0077]

5 Fig. 9 shows another example of the liquid crystal projector. The feature of Fig. 9 is that dichroic mirrors 92 and 93 are used instead of the cross dichroic prism 91 (or a cross dichroic mirror). Comparing with the cost in the case of using the cross dichroic prism 91 or cross dichroic mirror, the cost of the optical system using the dichroic mirrors is lower. Besides, the advantage that the light
10 lengths of R, G, and B are equivalent is achieved by composing as Fig. 9.

[0078]

Fig. 10 shows another example of the liquid crystal projector. The combining optical system 90 is composed of reflecting mirrors 81 and 82, and the cross dichroic prism 91 (or a cross dichroic mirror).

15 [0079]

Three liquid crystal panels are used in Figs. 1, 9 and 10. It is also acceptable to apply time sharing system (time sharing system) by using one liquid crystal panel 74 as shown in Figs. 44 and 45. In this case, the liquid crystal panel 74 needs to have the switching speed three-times as fast as usual. The
20 response speed of a regular TN type (twisted nematic type) liquid crystal is 10 through several decades ms. Therefore, a ferroelectric liquid crystal whose response speed is around 0.1 ms or a semi-ferroelectric liquid crystal whose response speed is around 1.5 ms can be used for this case.

[0080]

25 Fig. 11 shows a configuration of a liquid crystal projector applying a

reflection type liquid crystal panel. The liquid crystal projector of Fig. 11 is composed of reflection type liquid crystal panels 76, 77 and 78 and polarization beam splitters 41, 42 and 43.

Fig. 12 shows an operation basic of the polarization beam splitter 41 and the reflection type liquid crystal panel 76. When a wave P is generated by the LD array 51, the wave P is transmitted through the polarization beam splitter 41 to be projected on the reflection type liquid crystal panel 76. A Reflected ray from the reflection type liquid crystal panel 76 returns to the polarization beam splitter 41 as a wave S. Since the polarization beam splitter 41 reflects the wave S, a ray reflected by the polarization beam splitter 41 goes in the right-angled direction with respect to the wave P.

[0081]

Fig. 13 shows another configuration of liquid crystal projector applying the reflection type liquid crystal panel as well as Fig. 12. The advantage of the configuration shown in Fig. 13 is that the light lengths of R, G, and B are equivalent on the plane allocation.

[0082]

Fig. 14 shows a configuration applying a polymer-dispersed liquid crystal panel. In Fig. 14, a polymer-dispersed liquid crystal panel 75, the projection lens 95 and a pin hole plate 97 are installed between the lens array 61 and the screen 96. Fig. 14 (a) shows the state that the polymer-dispersed liquid crystal panel 75 is ON and an image is displayed. Fig. 14 (b) shows the state that the polymer-dispersed liquid crystal panel 75 is OFF and no image is displayed. The feature of the configuration in which the polymer-dispersed liquid crystal panel 75 and the projection lens 95 are assembled is that high-contrast can be achieved because

radiated rays are parallel beams. The smaller a pin hole diameter D of the pin hole plate 97 is, the better the contrast ratio becomes. It is necessary that the beam condensing rate of the projection lens 95 is high, in order to make the diameter D of the pin hole small. Therefore, it is desirable for incident beams
5 into the projection lens 95 to have a high parallel degree.

As set forth above, it is essential for the liquid crystal projector applying the polymer-dispersed liquid crystal panel to receive beams having a high parallel degree. By using the LD array 51 of the present invention, beams of a high parallel degree can be generated.

10 The polymer-dispersed liquid crystal panel operates regardless of the polarization direction of incident beams. Therefore, whatever beam wave the LD array 51 outputs, that is either a wave S or a wave P, or both the waves S and P, the polymer-dispersed liquid crystal panel operates without any problems.

By using the LD array 51 and the lens array 61 of the present invention, the
15 contrast ratio of the liquid crystal projector applying the polymer-dispersed liquid crystal panel is increased and a utilizing efficiency of optical energy is enhanced. Comparing with a liquid crystal panel utilizing a polarization direction difference, it is possible to obtain a wider perspective angle.

[0083]

20 In addition, it is acceptable to apply the present invention not only to the liquid crystal projector but also to a direct-view type liquid crystal display apparatus which will be stated in Embodiment 6. When the present invention is applied to the direct-view type liquid crystal display apparatus, the advantage of wider perspective angle can be also obtained. Besides, the present invention has
25 an advantage that a color filter can be unnecessary.

[0084]

In Fig. 3, the case that semiconductor lasers 54 are arrayed to compose the LD array 51 is shown. It is also acceptable to array light emitting diodes (LED), electro-luminescence lamps (EL), discharge lamps, or other luminous devices instead of the semiconductor lasers 54.

[0085]

Embodiment 2.

Fig. 15 shows a liquid crystal projector according to the present invention. In Fig. 15, the luminous device 50 is composed of arrayed plural discharge lamps 58 and the parallel-conversion optical system 60 is composed of arrayed plural reflectors 68. A lamp array 57 is composed of the discharge lamps 58 and the reflectors 68. A polarization-conversion system 85 is composed of a lens array 86, a polarization beam splitter 87, a $\lambda/2$ plate 88 and a lens array 89. The lamp array 57 is composed of arrayed micro lamps or mini lamps.

[0086]

Fig. 16 shows a perspective view of the lamp array 57, and Fig. 17 shows a front view of it. The lamp array 57 is composed of arrayed discharge lamps 58 and reflectors 68 corresponding to the discharge lamps 58.

[0087]

The arc length can be short since the small lamps stated above are used. Therefore, the reflected lights from the reflectors 68 can be closer to the perfect parallel beams. Namely, parallel beams are output from the lamps having point source lamps. A controller 48 controls light emission of each discharge lamp 58 in the lamp array 57. The controller 48 can respectively turn on or off the discharge lamps 58, and change the light emission amount of the discharge lamp 58.

Luminance can be variable by respectively controlling output beams from the discharge lamps 58. By dint of making the luminance variable, it becomes possible to remove unevenness in the projected image and make the luminance uniform. It is also possible to change the beam section shape to be a rectangle, square, triangle or circle by selecting discharge lamps 58 to be emitted, based on the control of the controller 48. Namely, light emission having no useless lights can be made by turning on only the discharge lamps 58 arranged to be the same shape as the lights to be used.

[0088]

Parallel beams output from the lamp array 57 are input into the lens array 86. The beams through the lens array 86 are collected onto the polarization beam splitter 87. Only waves P are passed through the lens array 86 and waves S are reflected. The reflected waves S are reflected by the mirror and input into the $\lambda/2$ plate 88. The input waves S are converted into waves P by the $\lambda/2$ plate 88 and output. The lens array 89 converts the waves P output from the polarization beam splitter 87 and the $\lambda/2$ plate 88, into parallel beams. These parallel beams are separated by using the dichroic mirror 92 and the dichroic mirror 93.

Red beams separated by the dichroic mirror 92 are reflected by the reflecting mirrors 81 and 82, and input into the red-transmission type liquid crystal panel 71.

Green beams separated by the dichroic mirror 93 are reflected by the reflecting mirrors 83 and 84, and input into the green-transmission type liquid crystal panel 72. Beams modulated by the red-transmission type liquid crystal panel 71, the green-transmission type liquid crystal panel 72, and the blue-transmission type liquid crystal panel 73 are combined by the cross dichroic prism 91 (or cross dichroic mirror). Then, the combined beams are output to the projection lens 95.

[0089]

Fig. 18 shows a perspective view of unified lamp array 57 and polarization-conversion system 85. Down-sizing can be accomplished by unifying as the above.

[0090]

5 Fig. 19 shows a liquid crystal display apparatus of single plate type. This liquid crystal display apparatus is made by combining the transmission type liquid crystal panel 74 of a single plate type and a color filter 44 to the unified lamp array 57 and the polarization-conversion system 85 shown in Fig. 18.

By unifying the transmission type liquid crystal panel 74 of a single plate
10 type and the color filter 44, a smaller display apparatus can be realized.

[0091]

Fig. 20 illustrates the case of a reflection layer 46 being provided at a part of the discharge lamp 58. The reflection layer 46 can be provided on the inside wall of a glass 45 as shown in Fig. 20 (a), or on the outside wall of the glass 45 as shown
15 in Fig. 20 (b). Beams emitted between electrodes 47 are reflected by the reflection layer 46 and output as parallel beams. As the discharge lamp 58 shown in Fig. 20 does not have a separate reflector 68, it is possible to make a micro lamp.

[0092]

20 Fig. 21 shows another example of the lamp array 57. The lamp array in Fig. 21 is composed of different size lamps, for instance, a xenon lamp 98 of 100 watt and a metal halide lamp 99 of 400 watt. The xenon lamp 98 and the metal halide lamp 99 have different spectral distributions. Therefore, by aggregating light sources having different spectral distributions, the degree of freedom of selecting
25 a color temperature for a display image can be realized.

[0093]

The lamp array 57 shown in Fig. 22 has LEDs 59 arranged among the arrangements made by the discharge lamp 58 and reflector 68. It is also acceptable to embed the semiconductor laser 54 or the surface-emitting semiconductor laser 56 instead of the LED 59. The case of Fig. 22 has a merit that light sources having different spectral distributions can be combined.

Besides, in the case of Fig. 21 or Fig. 22, it is possible to select a lamp to be lightened or change a light shape to be emitted, by controlling the controller 48. Fig. 21 or Fig. 22 shows the case that the light source type (various discharge lamps, various LDs, various LEDs, etc.) can be changed and selected, the array shape of the light source can be changed and selected, and that light sources having different sizes are allocated. Then, of course, it is possible to perform other combinations in addition to the cases of Fig. 21 and Fig. 22.

[0094]

Fig. 23 shows a configuration for realizing higher luminance of the liquid crystal projector shown in Fig. 15. In the case of Fig. 23, a color screen of R, G, and B is created by using the wave S of the light source, and a luminance screen is created by using the wave P of the light source. By combining the waves P and S with using polarization beam splitter 41, a higher luminance screen can be created. As the conventional liquid crystal projector has one light source, a big light source is needed for realizing high luminance. Besides, since the heating is almost generated in the light source, the cooling has been a large problem to be solved. Also, it has been impossible to avoid effects of the light source spectral distribution characteristic on the image. According to the configuration of Fig. 23, two light sources are provided, so that the high luminance can be realized. Since

the two light sources having different spectral distributions are used, it is possible to avoid effects of the light source spectral distribution characteristic on the image. In addition, a light source having a small calorific value can be used for obtaining the same luminance as the conventional art, because two light sources are used.

5 It is also possible to distribute the heat generating place into two places.

Fig. 22 shows the case of the array lamp 57 being used. It is also acceptable to use a lamp, not the array type, as a light source like the conventional art.

[0095]

As stated above, the case that the discharge lamp whose lamp tube (discharge

10 tube) itself is the reflector has been explained in the present embodiment.

[0096]

The luminous device 50 in which plural lamps are arranged has also been explained.

[0097]

15 The controller 48 which respectively controls the lamp output of the lamp array 57 in order to make the luminance uniform or make the luminance variable has been explained.

[0098]

Besides, the lamp array 57 is made by aggregating lamps having different

20 spectral distributions has been explained. The lamp array 57 is made by aggregating discharge lamps of short arc (less than 4 mm), each of which has luminance more than hundreds of lm through tens of thousands of lm.

[0099]

It is also possible to adjust the lamp aggregation with the light-utilizing

25 shape. For instance, if the beam whose section is square is needed, the lamps can

be arranged like a square array. If the beam whose section is round is needed, the lamps can be physically arranged like a round aggregated shape.

The beam shape can be controlled based on ON or OFF of the lamp by the controller 48.

5 [0100]

It is also possible to adjust the lamp array 57 with the size of the light-utilizing shape.

[0101]

It is also possible to put some LEDs, LDs and so on among the lamps of the lamp array 57, or to compose the lamp array 57 of only LEDs, only LDs or only lamps.

[0102]

The lamp array can be adjusted with the lens array 86.

[0103]

15 The lens array 86 can be combined with the lamp light-outputting-place.

[0104]

According to the present Embodiment, it is possible to make the parallel beams output from the lamp large to any extent because the short arc lamps are used.

20 [0105]

The light source which is able to project a light amount up to the temperature tolerance of an optical element or the liquid crystal panel located at the downstream of the light beam can be obtained.

[0106]

25 Besides, an integrator for making the beam uniform is not necessary. The

function for making beams uniform by a fry eye lens (array lens) is also unnecessary.

[0107]

As the arc is short (as the point light source is used), it is easy to make
5 parallel beams and a high light-utilizing efficiency is realized.

[0108]

Converting the beam section from circle to square, which has been conventionally performed, is not necessary. As an effect of this, it is possible to enhance the light-utilizing efficiency equal to or more than 30 percent.

10 [0109]

Also, a color temperature can be optionally selected because some spectral distribution light is overlapped.

[0110]

The luminance of the projector can be changed to a large extent by using the
15 luminance of the light source.

[0111]

In the case of the shape of the lamp array 57 being the same as the light-utilization shape, the optical system or the collective lens located at the downstream of the light beam is not necessary.

20 [0112]

A color temperature can be further optionally selected by using the LED, LD and so forth as the light source.

[0113]

By making the light source be an array state, optical system components can
25 be omitted.

[0114]

As stated in Embodiment 1, when the linearly polarized beam is utilized, the polarization-conversion system can be omitted, and the heat radiation system can also be omitted because the light-utilization rate is enhanced.

5 [0115]

Embodiment 3.

Fig. 24 shows a configuration of the image display apparatus according to the present invention. The feature of Fig. 24 is that a white laser 39 is used as the light source. The white laser 39 outputs linearly polarized beams. As a concrete
10 example of the white laser 39, a gas laser of outside mirror type including a Brewster's window is introduced. The white laser 39 of Fig. 23 includes an element having a Brewster's window and a polarization characteristic, between the reflecting mirror 81 and a half mirror 79. Output beams from the half mirror 79 are linearly polarized parallel beams.

15 As an example of the white laser, a metal vapor laser can be used. For instance, He-Cd metal vapor laser excited by negative glow plasma can be used.

It is also acceptable to provide the beam-conversion optical system 65 for the output beams from the white laser 39, as shown in Fig. 25.

[0116]

20 Figs. 26 and 27 show other examples of the light source which outputs a strong beam like the linearly polarized beam. These light sources show examples of utilizing beams based on superradiation. The beam by the superradiation is not a laser beam but is a beam having an extremely high light intensity and a directivity as the beam by the superradiation receives induced emission.

25 The light source shown in Fig. 26 or 27 is composed of the electrode 47,

reflecting mirror 81 and a linear polarization element 49. Output beams from the light source become linearly polarized beams based on the superradiation, by the linear polarization element 49.

[0117]

5 Embodiment 4.

In the present embodiment, the LD array 51 and the beam-conversion optical system 65 stated in Embodiment 1 will now be concretely explained. With respect to the point that the luminance distribution projected on the red-transmission type liquid crystal panel 71 is uniform will also be explained. Though only the LD array 51 and the red-transmission type liquid crystal panel 71 are described in here, the same explanation as the below can be stated for other LD arrays and other liquid crystal panels.

[0118]

Fig. 37 shows the case that the LD array 51 is larger than the red-transmission type liquid crystal panel 71. In Fig. 37, the semiconductor lasers 54 are arranged on the plane of the LD array 51. Beams emitted from the semiconductor lasers 54 are projected on a convex lens 116. A luminescence center axis 112 of the beams emitted from the semiconductor laser 54 is parallel to a system optical axis 113. As the semiconductor lasers 54 are arranged on the plane, the luminescence center axes 112 of the beams from the semiconductor lasers 54 are parallel to the system optical axis 113. Beams through the convex lens 116 are input into a convex lens 117 as beams 122. Beams through the convex lens 117 become parallel beams 120. The parallel beams 120 are collected by a convex lens 118. Beams from the convex lens 118 are input into a concave lens 115 and converted into parallel beams 121. The parallel beams 121 are

projected on the red-transmission type liquid crystal panel 71. A luminance distribution 130 indicates a light distribution projected on the red-transmission type liquid crystal panel 71. Beams emitted from the semiconductor lasers 54 have Gaussian distribution. Beams projected on the red-transmission type liquid crystal panel 71 have uniform luminance distribution because the beams having Gaussian distributions are overlapped .

[0119]

Fig. 38 shows the case of the LD array 51 being curved. Fig. 39 shows the configuration of the LD array 51 of Fig. 38. As shown in Fig. 39, plural semiconductor lasers 54 are two-dimensionally arranged on a concave substrate 140. A center of curvature 111 of the curved surface of the concave substrate 140 exists on the system optical axis 113. Therefore, the luminescence center axes 112 of the semiconductor lasers 54 are converged on the center of curvature 111. The semiconductor lasers 54 on the LD array 51 of Fig. 39 are arranged in order to converge the beams of the semiconductor lasers 54.

[0120]

As shown in Fig. 38, the luminescence center axes 112 of the beams emitted from the semiconductor lasers 54 are converged on the center of curvature 111 and converted by the beam-conversion optical system 65. The beam-conversion optical system 65 is composed of the convex lens 116 and the concave lens 115. The beams are converted to the parallel beams 120 by the concave lens 115 and projected onto the red-transmission type liquid crystal panel 71. The luminance distribution 130 of the beams projected on the red-transmission type liquid crystal panel 71 becomes, as set forth above, uniform because the beams are overlapped.

[0121]

Now, the case of the LD array 51 being smaller than the red-transmission type liquid crystal panel 71 will be explained.

Fig. 40 shows the case of the LD array 51 in which the semiconductor lasers 54 are arranged on the plane so that the luminescence center axes 112 of the beams emitted from the semiconductor lasers 54 may be parallel to the system optical axis 113. The beams emitted from the semiconductor lasers 54 become the beams 122 through the convex lens 116, and further become the parallel beams 120 through the convex lens 117. The parallel beams 120 are made to be diverging through the convex lens 118 and input to a convex lens 119. The beams through the convex lens 119 become the parallel beams 121 and projected onto the red-transmission type liquid crystal panel 71. The luminance distribution 130 of this case is also uniform.

[0122]

Fig. 42 shows the case that the semiconductor lasers 54 are arranged on the curved surface of the LD array 51. Fig. 42 illustrates the configuration of the LD array 51 of Fig. 41. The plural semiconductor lasers 54 are two dimensionally arranged on a convex substrate 141. The center of curvature 111 of the convex substrate 141 exists on the system optical axis 113. Accordingly, the luminescence center axes 112 of the beams emitted from the semiconductor lasers 54 are converged on the center of curvature 111.

[0123]

In Fig. 41, the size of the beams emitted from the semiconductor lasers 54 is converted at the beam-conversion optical system 65. The beams emitted from the semiconductor lasers 54 are made to be wide through the concave lens 115 and input to the convex lens 119. The beams input to the convex lens 119 are

converted to the parallel beams 120 and projected onto the red-transmission type liquid crystal panel 71. The luminance distribution 130 of this case is also uniform.

[0124]

5 Embodiment 5.

Fig. 46 shows the beam-conversion optical system 65 applying an analog phase control using a modified curve surface lens 151 (aspheric lens). Conventionally, it has been attempted to change the intensity distribution of optical beam depending upon a purpose. For example, the fry eye lens or
10 kaleidoscope is known as a beam homogenizer. These are based on overlapping a lot of beams. As another method, as shown in Fig. 46, it is possible to condense or expand the light intensity of a fine part of an incident beam one by one in order to convert the light intensity distribution to an aimed one. Concretely, the shape of a conversion element can be decided by the following processes (algorithm). To
15 make the explanation simple, it is supposed to have a one-dimensional beam distribution. As an example, the intensity distribution A in Fig. 47 (a) is converted to the intensity distribution B.

When an included energy of each distribution intensity is integrated with respect to the position, it is supposed to have the state of Fig. 47 (b). As it is
20 supposed to convert 100 %, each included energy of the both is standardized to be 1. When the energy is reapplied from the edge, the correlation between the point X_A on the line A and the point X_B on the line B for performing a desired conversion is shown in Fig. 48. As the included energy is expressed by a monotonic increasing function, the correlation should necessarily be 1 to 1. Therefore, a pair of
25 mapping (coordinate conversion) $X_B = T(X_A)$ can be defined.

As shown in Fig. 49, in order to convert a beam of A to be away by the distance L, it may be enough that rays on A should have an angle θ (phase contrast). The figure of the optical element for giving the angle θ can be easily calculated by the equation shown in Fig. 49.

5 The conversion element obtained as the result controls the phase of incident beam in analog. Characteristics of the beam forming by the analog phase control are as follows:

- * Almost 100 % efficiency can be obtained.
- * Beam quality (coherency) is not deteriorated.

10 [0125]

Fig. 50 illustrates the modified curve surface lens 151 based on the analog phase control being applied to the liquid crystal projector. The screen luminance and the uniformity can be improved.

15 The experiment for proving the principle has been executed by making a modified curve surface lens 151 using acrylic acid resin as a trial and applying the modified curve surface lens 151 to the liquid crystal projector. In the case shown in Fig. 51 of collecting lights by using a general lens, it is necessary to throw away more than half the lights in order to obtain the screen illuminance uniformity because a circle light intensity distribution focused on the central part of the liquid crystal panel is generated. By using the modified curve surface lens 151 as shown in Fig. 52, lights being a rectangle to be suited for the liquid crystal panel shape and having a uniform distribution can be obtained. Consequently, it has been proved as the experiment result shown in Fig. 53 that the uniformity of illuminance distribution on the screen is high and the luminous flux amount on the screen is increased to be more than twice.

20

25

[0126]

The beam shape conversion theory stated above is also effective in the laser. It is expected that the conversion as shown in Fig. 54 can be achieved without lowering the substantial coherency.

5 [0127]

As stated above, parallel beams whose luminance distribution is further uniform can be obtained by using the modified curve surface lens 151. There are two methods as to the luminance distribution uniformity: one is a method of using the modified curve surface lens 151 and the other is described in Embodiment 4
10 with reference to Figs. 37 through 42. Besides, it is acceptable to combine the two methods.

[0128]

Embodiment 6.

In the above Embodiment, the projection type display apparatus has been
15 explained. In the present Embodiment, direct-view type display apparatus will now be explained.

Fig. 55 shows a configuration of the direct-view type display apparatus. Fig. 55(a) illustrates the front view of an LD array 152. Plural groups, each of which is composed of semiconductor lasers 54R emitting a light for red, 54G
20 emitting a light for green and 54B emitting a light for blue, are arranged in the LD array 152. Namely, each of the groups is composed of semiconductor lasers having different wavelengths (different colors) and each of the groups is provided for one pixel of the liquid crystal panel 74. Fig. 55(b) illustrates the side view of the direct-view type display apparatus. Beams emitted from the LD array 152
25 are input to an array lens 153 and converted to parallel beams. The parallel

beams are further input to the modified curve surface lens 151 for realizing the luminance distribution uniformity. Beams output from the modified curve surface lens 151 are projected onto the liquid crystal panel 74. Since the projected beams have uniform luminance distribution, even images can be displayed.

[0129]

The LD array 152 is composed as stated in reference to Fig. 3, 6, 7, or 8. Especially, the number of components can be reduced by using the surface-emitting semiconductor laser 56 shown in Fig. 8.

[0130]

Now, the operation will be stated. The three semiconductor lasers 54R, 54G, and 54B are lit in turn in time sharing. The liquid crystal panel 74 modulates lights emitted by being synchronous with the light lit in time sharing.

The response rate of the semiconductor laser is several ns and it is possible to switch the semiconductor laser in time sharing. Particularly when the surface-emitting semiconductor laser is used, the modulation rate is 10 GHz (that is, the response rate is 0.1 ns, which is equal to or more than ten times as high as that of the general semiconductor laser.). The rate is high enough to control each pixel one after another. For example, $1280 \times 1024 \times 60$ (Hz, frame rate) = 0.0786×10^9 , which corresponds to 12.7ns. If this rate is shared among the colors, the rate for each color is 12.7/3 ns (almost 4.2ns), which is enough to control each pixel one by one.

[0131]

Fig. 56 shows a side view of the direct-view type display apparatus applying the surface-emitting semiconductor laser. A feature of this apparatus is that the

liquid crystal panel is not used. The surface-emitting semiconductor laser is directly modulated to display an image. As set forth above, since the modulation rate of the surface-emitting semiconductor laser is fast enough to control each pixel one by one, it is possible to display images by using the method of directly
5 modulating the surface-emitting semiconductor laser.

[0132]

Fig. 57 shows another configuration of the direct-view type display apparatus. Fig. 57(a) shows a front view of the LD array 152. Plural groups, each of which is composed of semiconductor lasers 54R emitting a light for red, 54G emitting a
10 light for green and 54B emitting a light for blue, are arranged in the LD array 152. In the case of Fig. 55, each of the groups is composed of semiconductor lasers having different wavelengths (different colors) and each of the groups is provided for one pixel of the liquid crystal panel 74. The semiconductor lasers 54R, 54G, and 54B of the present case do not particularly correspond to one pixel of the
15 liquid crystal panel 74.

Fig. 57(b) illustrates a side view of the direct-view type display apparatus. Beams emitted from the LD array 152 are projected onto the liquid crystal panel 74. The beams from the LD array 152 lie upon another on the liquid crystal panel 74. If the distance L between the LD array 152 and the liquid crystal panel 74 is
20 5 through 10 mm, more than half the beams next to each other lie upon each other, which makes the luminance distribution of the projected beams uniform to display even images.

[0133]

Fig. 58 shows a projection type of the time sharing display apparatus of
25 single plate type shown in Fig. 57. Both of the LD array 152 and the liquid

crystal panel 74 are single plates, similar to those in Fig. 57, and operate in time sharing. Beams transmitted through the liquid crystal panel 74 are converted into almost parallel beams by the array lens 153 (parallel-conversion optical system 60).

5 [0134]

[Effects of the Invention]

As set forth the above, according to the present invention, there is an effect that the polarization-conversion optical system is not necessary because the linearly polarized beam is utilized.

10 [0135]

According to the present invention, unnecessary heat radiation can be lessened and the heat radiation system can be omitted, because the light-utilization rate is enhanced.

[0136]

15 According to the present invention, it is easy to generate parallel beams.

[0137]

According to the present invention, down-sizing and low-cost can be realized because the optical system is simplified.

[0138]

20 According to the present invention, high luminance of image and quality enhancement of image can be realized.

[Brief Explanation of the Drawings]

Fig. 1 shows a configuration of a liquid crystal projector according to the present invention;

25 Fig. 2 shows a configuration of LD array 51 and lens array 61, according to

the present invention;

Fig. 3 shows a front view of the LD array 51 according to the present invention;

Fig. 4 shows a perspective view of a semiconductor laser 54, according to the present invention;

Fig. 5 shows a beam-conversion optical system 65 according to the present invention;

Fig. 6 shows another example of the LD array 51 according to the present invention;

Fig. 7 shows a surface-emitting semiconductor laser 56 according to the present invention;

Fig. 8 shows a perspective view of the surface-emitting semiconductor laser 56 according to the present invention;

Fig. 9 shows another example of the liquid crystal projector according to the present invention;

Fig. 10 shows another example of the liquid crystal projector according to the present invention;

Fig. 11 shows another example of the liquid crystal projector according to the present invention;

Fig. 12 shows an operation of polarization beam splitter 41 and reflection type liquid crystal panel 76, according to the present invention;

Fig. 13 shows another example of the liquid crystal projector according to the present invention;

Fig. 14 shows a configuration of liquid crystal projector applying a polymer-dispersed liquid crystal panel 75, according to the present invention;

Fig. 15 shows a configuration of liquid crystal projector applying a lamp array 57, according to the present invention;

Fig. 16 shows a perspective view of the lamp array 57 according to the present invention;

5 Fig. 17 shows a front view of the lamp array 57 according to the present invention;

Fig. 18 shows a unified lamp array 57 and discharge lamp 58 according to the present invention;

10 Fig. 19 shows a configuration of unified single plate type liquid crystal projector according to the present invention;

Fig. 20 shows a discharge lamp 58 according to the present invention;

Fig. 21 shows another configuration of the lamp array 57 according to the present invention;

15 Fig. 22 shows another configuration of the lamp array 57 according to the present invention;

Fig. 23 shows a liquid crystal projector for combining a color image and a luminance image, according to the present invention;

Fig. 24 shows a liquid crystal projector applying a white laser 39, according to the present invention;

20 Fig. 25 shows the white laser 39 and the beam-conversion optical system 65, according to the present invention;

Fig. 26 shows a light source applying a linear polarization element 49, according to the present invention;

25 Fig. 27 shows another light source applying the linear polarization element 49, according to the present invention;

Fig. 28 shows a conventional polarization illumination apparatus;

Fig. 29 shows a first lens plate of the conventional polarization illumination apparatus;

Fig. 30 shows a polarization separation prism array of the conventional polarization illumination apparatus;

Fig. 31 shows a conventional projection type display apparatus;

Fig. 32 shows comparison regarding conventional lamps;

Fig. 33 shows an emission distribution according to a conventional art;

Fig. 34 shows a conventional lamp;

Fig. 35 shows an optical path length and a light shading, according to a conventional art;

Fig. 36 shows a light-utilizing rate according to a conventional art;

Fig. 37 shows the LD array 51 and the beam-conversion optical system 65, according to the present invention;

Fig. 38 shows the LD array 51 and the beam-conversion optical system 65, according to the present invention;

Fig. 39 shows the LD array 51 according to the present invention;

Fig. 40 shows the LD array 51 and the beam-conversion optical system 65, according to the present invention;

Fig. 41 shows the LD array 51 and the beam-conversion optical system 65, according to the present invention;

Fig. 42 shows the LD array 51 according to the present invention;

Fig. 43 shows a conventional three color image projector;

Fig. 44 shows a liquid crystal projector of single plate type applying time sharing system, according to the present invention;

Fig. 45 shows another liquid crystal projector of single plate type applying time sharing system, according to the present invention;

Fig. 46 shows the beam-conversion optical system applying a modified curve surface lens 151, according to the present invention;

5 Fig. 47 shows an intensity distribution and an included energy, according to the present invention;

Fig. 48 shows a corresponding relation of the included energy, according to the present invention;

Fig. 49 illustrates calculating a specific angle (phase contrast) for a beam,
10 according to the present invention;

Fig. 50 shows a configuration of a liquid crystal projector applying the modified curve surface lens, according to the present invention;

Fig. 51 illustrates collecting lights by using a general lens;

Fig. 52 illustrates collecting lights by using the modified curve surface lens,
15 according to the present invention;

Fig. 53 shows a compared relation in the case of the modified curve surface lens and the general lens being applied, according to the present invention;

Fig. 54 shows an example of a beam conversion for a laser, according to the present invention;

20 Fig. 55 shows a direct-view type display apparatus applying a time sharing system, according to the present invention;

Fig. 56 shows a direct-view type display apparatus applying a time sharing system with using no liquid crystal panel, according to the present invention;

Fig. 57 shows a direct-view type display apparatus applying a time sharing
25 system, according to the present invention; and

Fig. 58 shows a projection type display apparatus applying a time sharing system, according to the present invention.

[Explanation of the Signs]

39 white laser. 41, 42, 43, 87 polarization beam splitters. 44 color filter.
5 45 glass. 46 reflection layer. 47 electrode. 48 controller.
49 linear polarization element. 50 luminous device. 51, 52, 53 LD arrays.
54, 55 semiconductor lasers. 56 surface-emitting semiconductor laser. 57 lamp
array. 58 discharge lamp. 59 LED. 60 parallel-conversion optical system. 61,
62, 63, 86, 89 lens arrays. 65 beam-conversion optical system. 66, 67 convex
10 lenses. 68 reflector. 69 liquid crystal panel for luminance. 70 optical switch.
71 red-transmission type liquid crystal panel. 72 green-transmission type liquid
crystal panel. 73 blue-transmission type liquid crystal panel. 74 transmission
type liquid crystal panel of single plate. 75 polymer-dispersed liquid crystal
panel. 76, 77, 78 reflection type liquid crystal panels. 79 half mirror. 80
15 display optical system. 81, 82, 83, 84 reflecting mirrors. 85 polarization-
conversion system. 88 $\lambda/2$ plate. 90 combining optical system. 91 cross
dichroic prism. 92, 93, 94 dichroic mirrors. 95 projection lens. 96 screen. 97
pin hole plate. 98 xenon lamp. 99 metal halide lamp. 111 center of curvature.
112 luminescence center axis. 113 system optical axis. 114 optical axis. 115
20 concave lens. 116, 117, 118, 119 convex lenses. 120, 121 parallel beams. 122
beam. 130 luminance distribution. 131 emission distribution. 140 concave
substrate. 141 convex substrate.

[Document Name] Abstract

[Summary]

[Objects] To obtain a liquid crystal projector in which an optical system is simple and a high light-utilization rate is realized.

5 [Means for Solving Problems]

A liquid crystal projector is composed of a luminous device 50, a parallel-conversion optical system 60, an optical switch 70, and a display optical system 80. The luminous device 50 applies LD arrays 51, 52 and 53 composed of semiconductor lasers 54 arrayed lengthwise and crosswise. Output beams from
10 the semiconductor lasers 54 are converted into parallel beams through lens arrays 61, 62 and 63. Since the output beams from the semiconductor lasers 54 are linearly polarized beams of wave P or wave S, the polarization conversion optical system is unnecessary. By optionally combining the semiconductor lasers 54, it is possible to make the shape of the LD array 51, 52 or 53 be the same as the light-
15 utilization shape of red-transmission type liquid crystal panel 71, green-transmission type liquid crystal panel 72, or blue-transmission type liquid crystal panel 73.

[Selected Drawing] Fig. 1

Fig.1

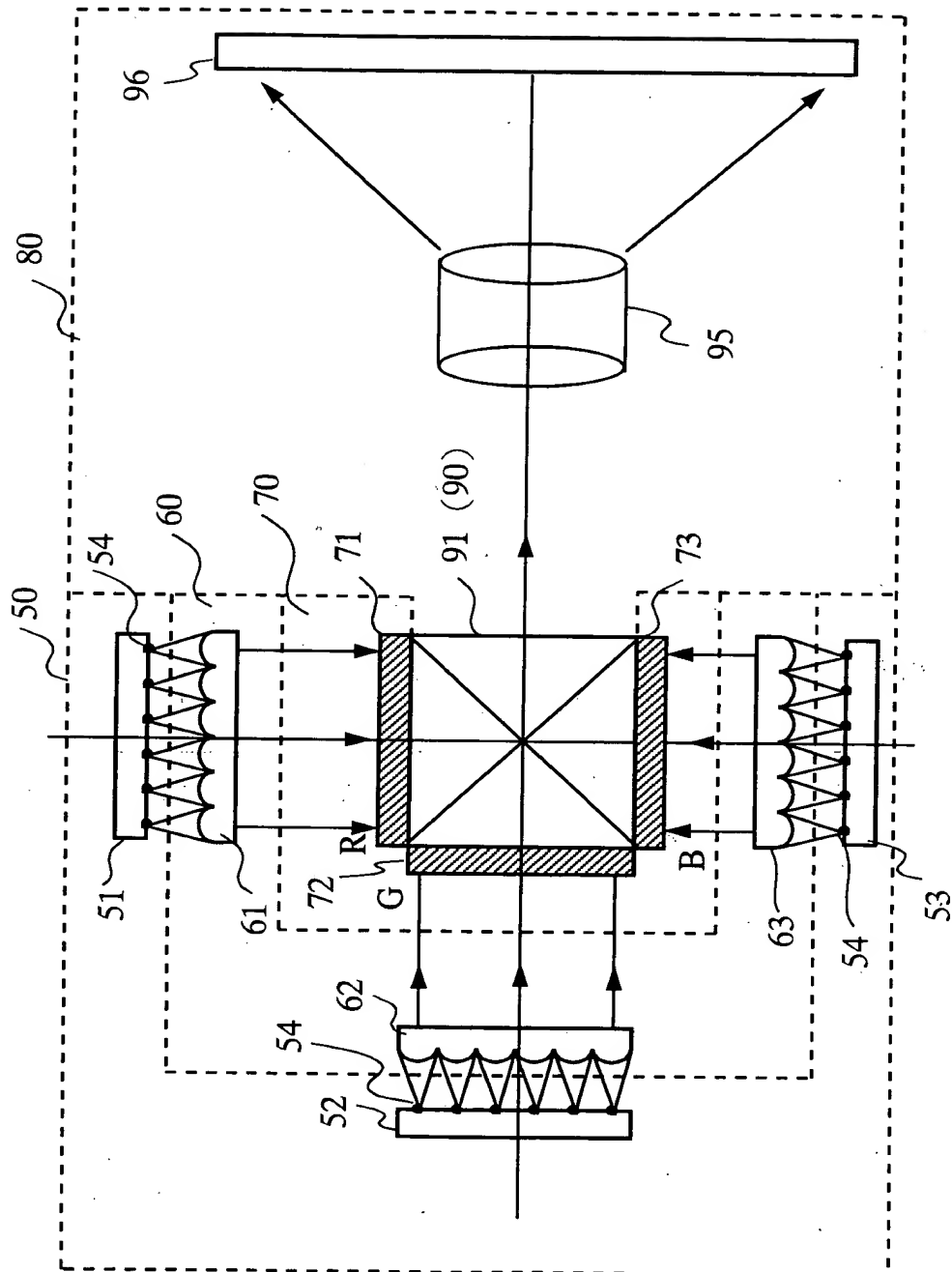


Fig.2

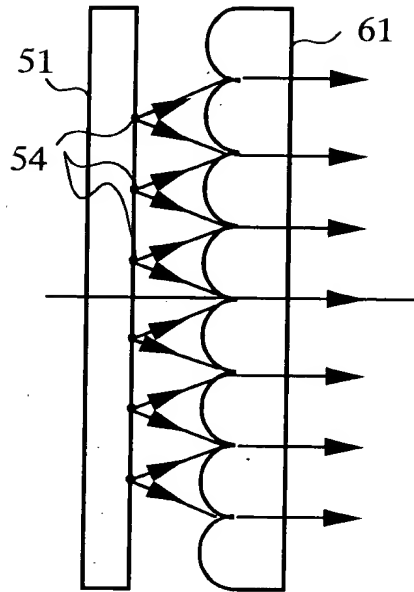


Fig.3

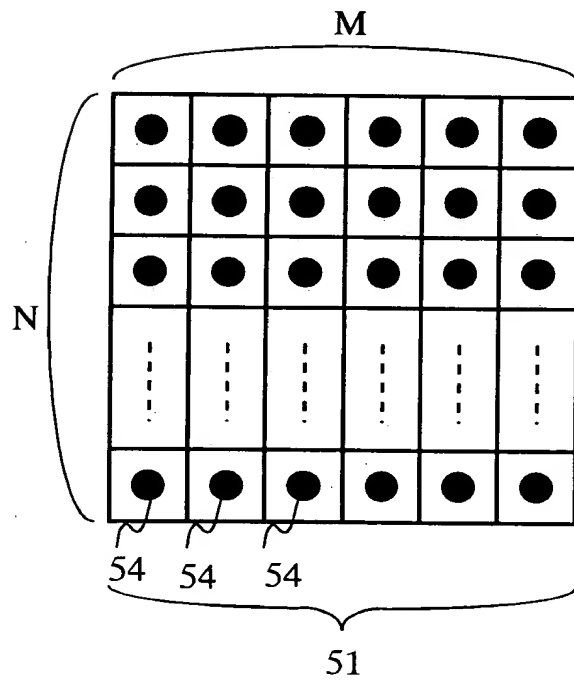


Fig. 4

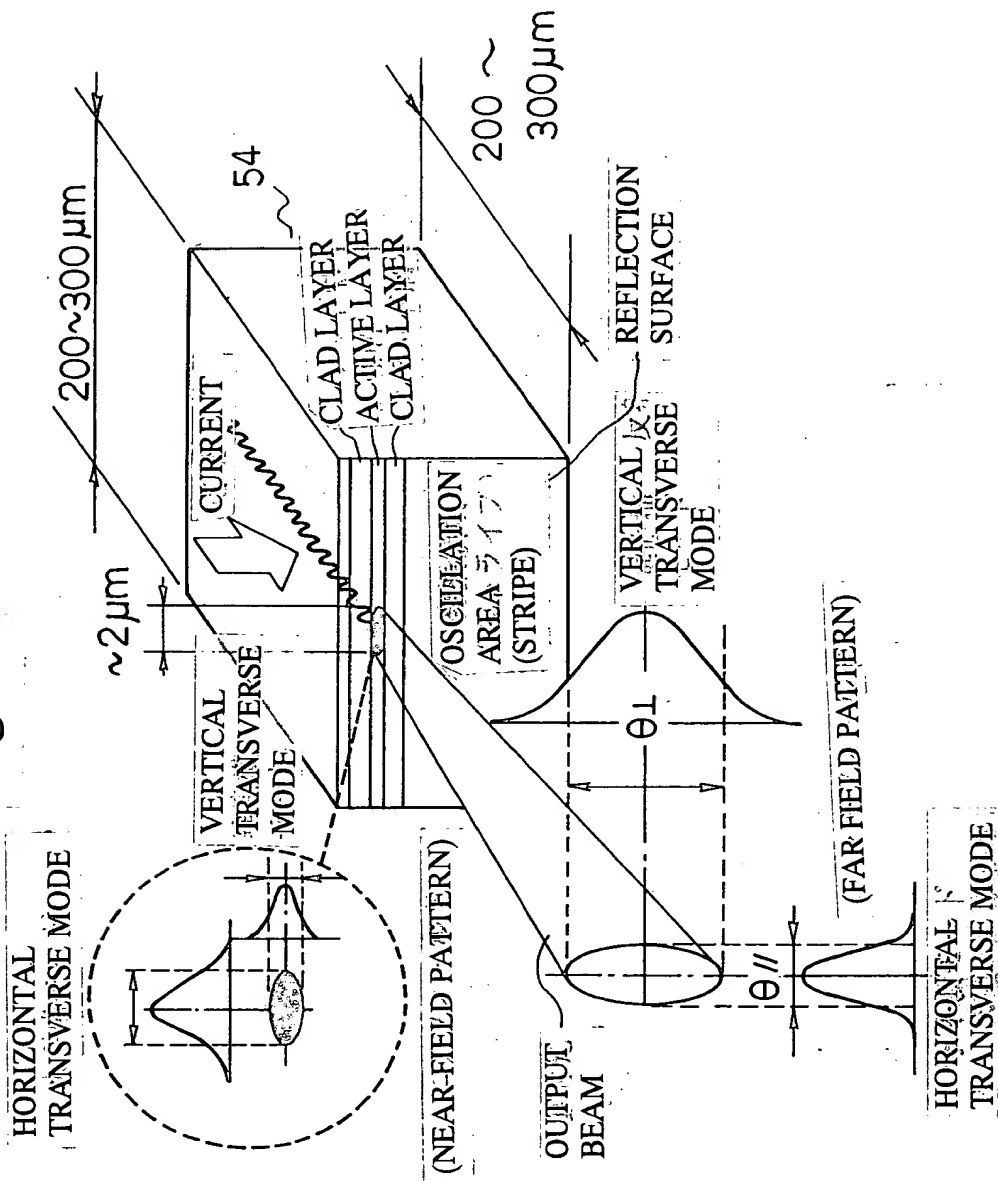


Fig.5

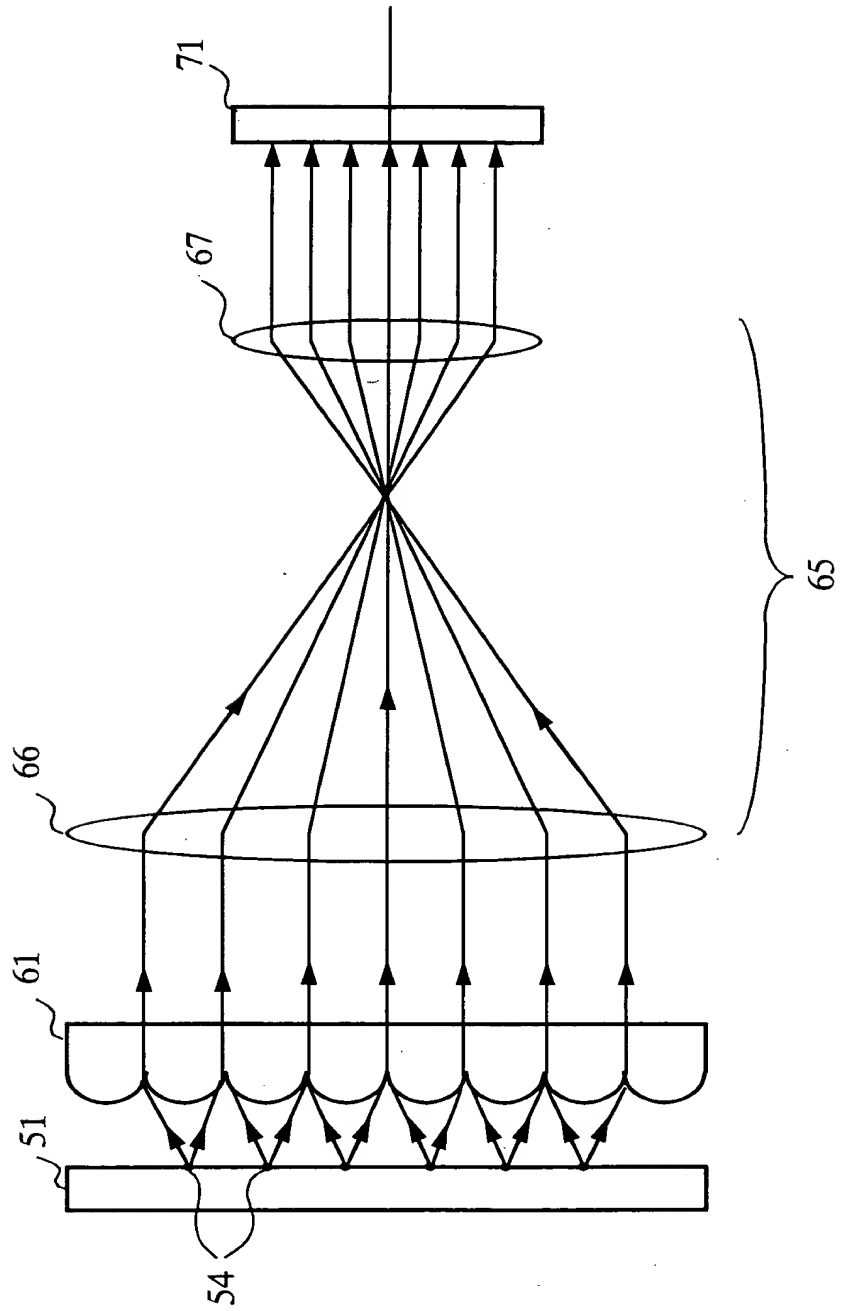


Fig.6

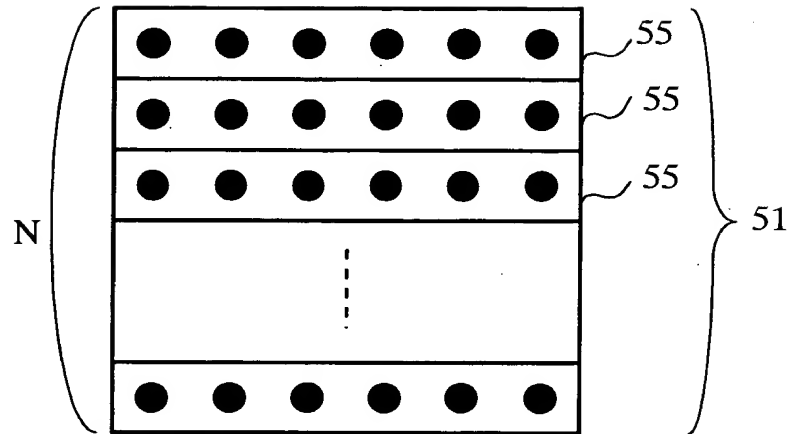
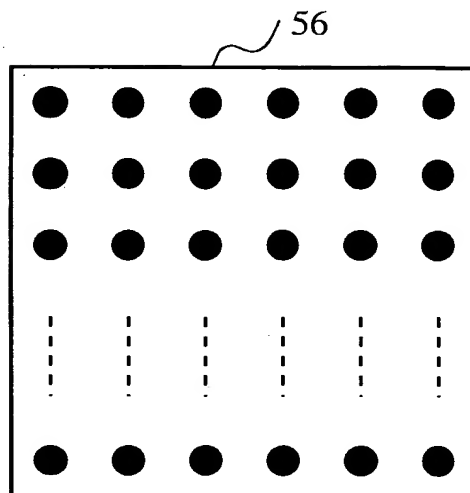


Fig.7



6/66 46

Fig. 8

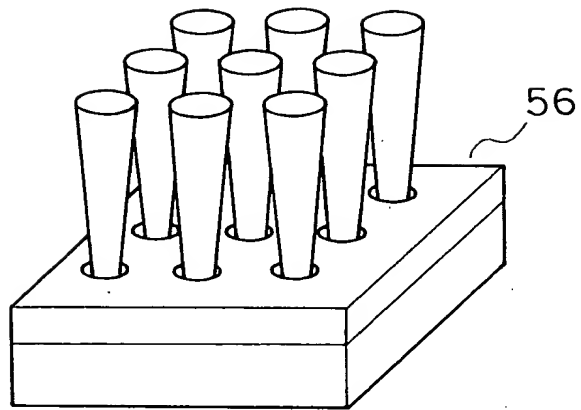


Fig. 9

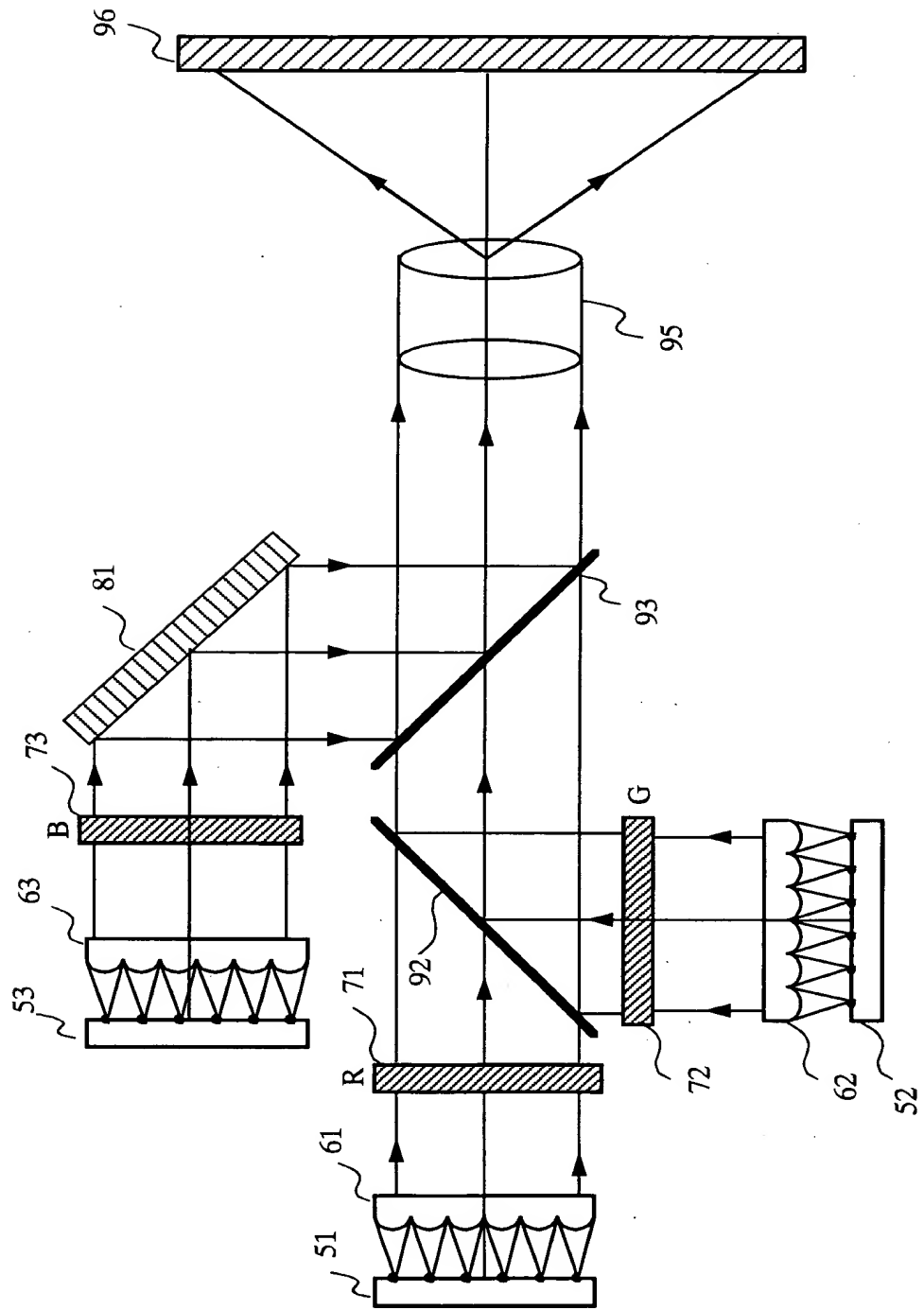
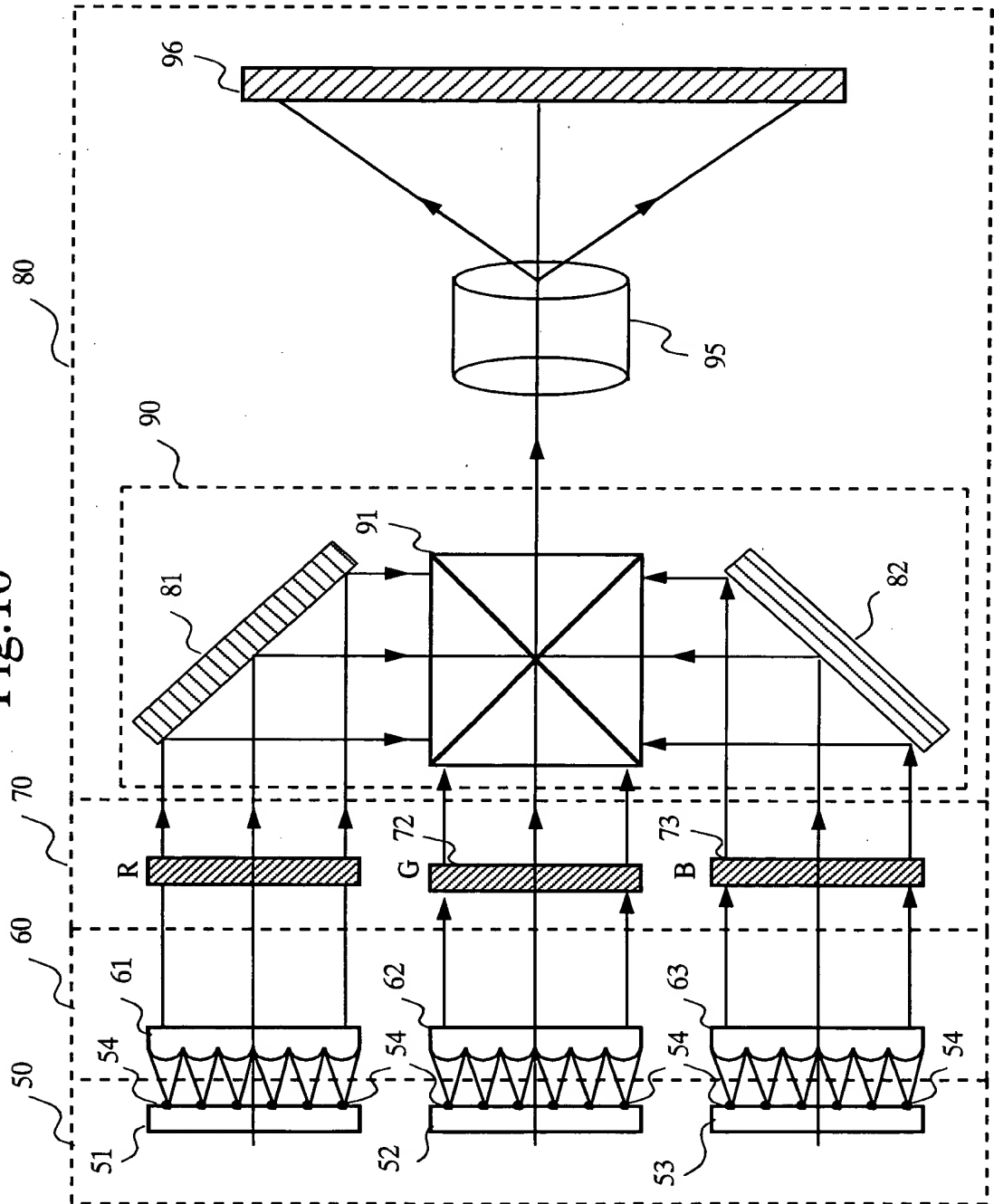
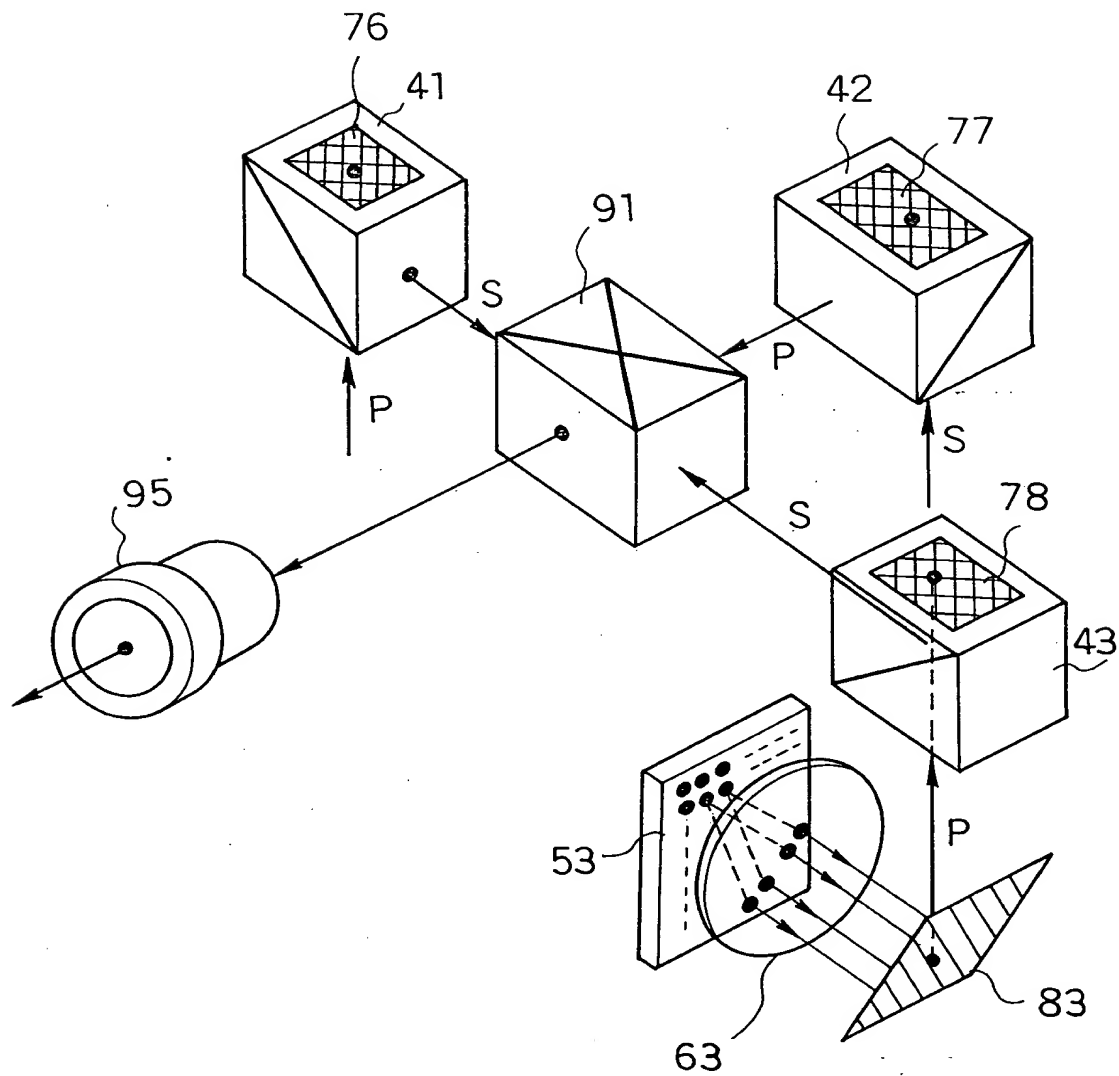


Fig.10



9/66 46

Fig. 11



10/66 46

Fig.12

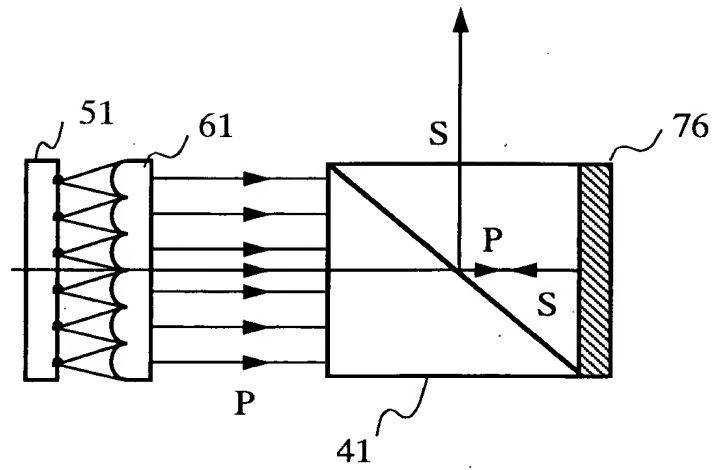
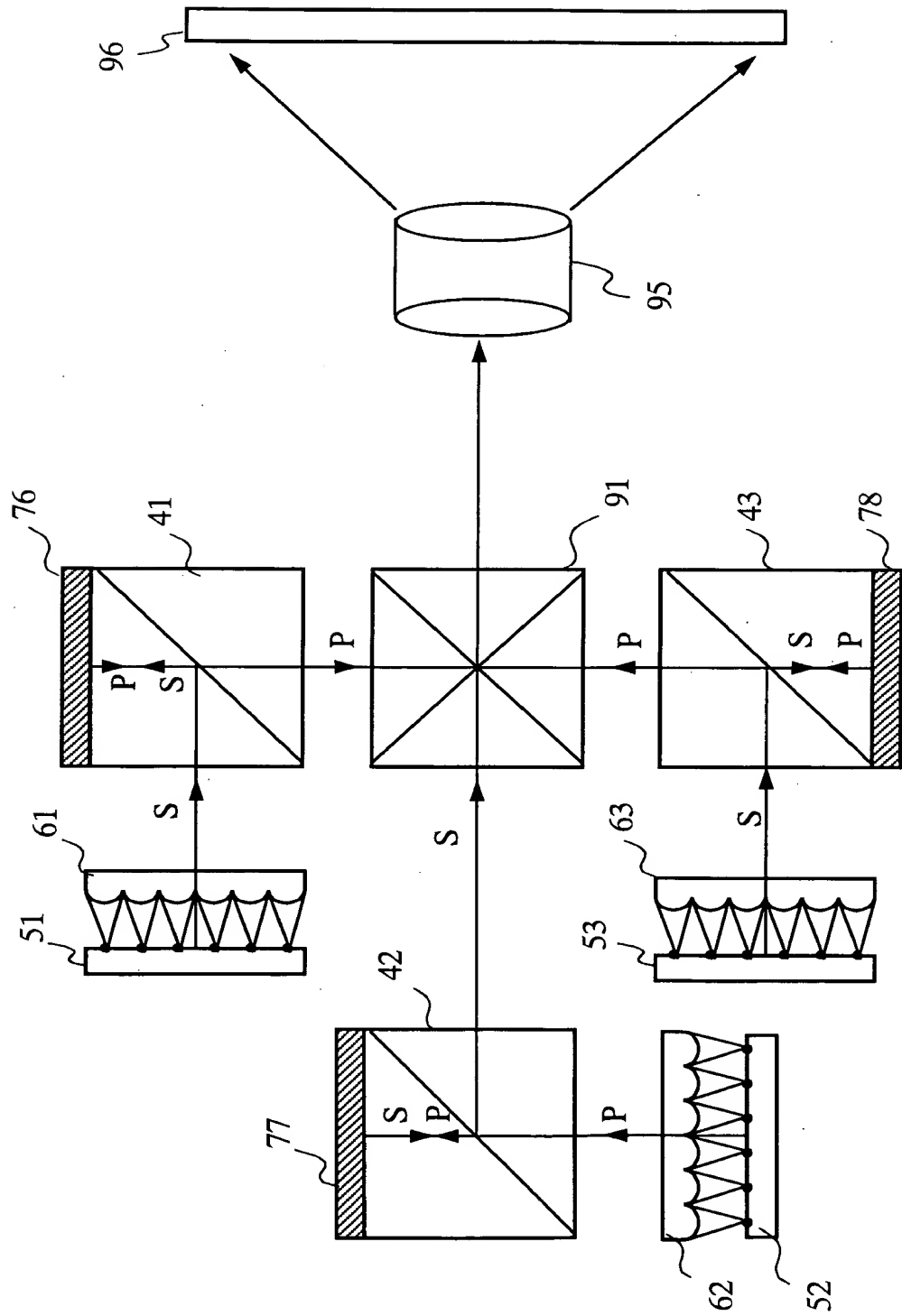


Fig.13



12/66 46

Fig.14

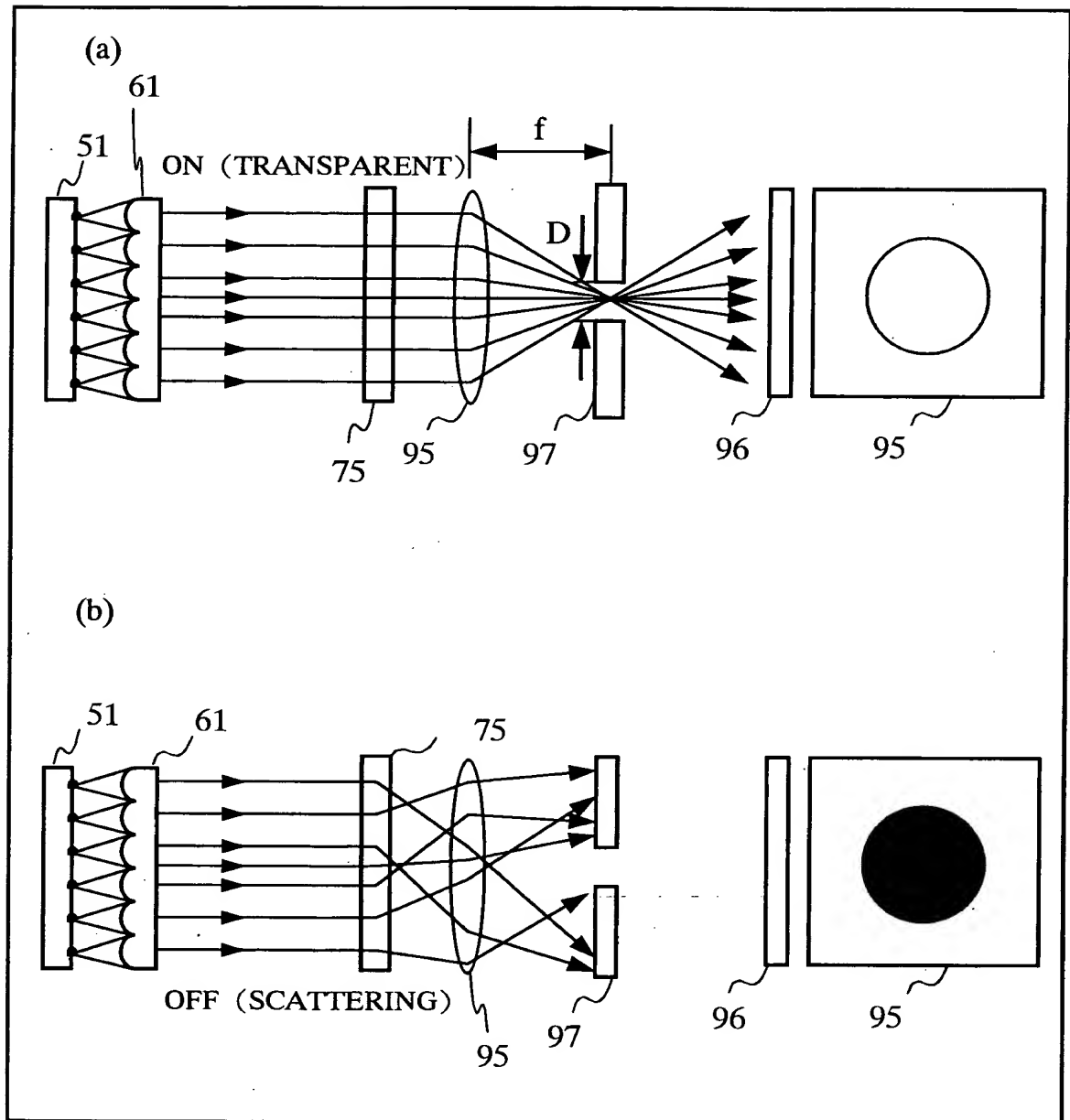
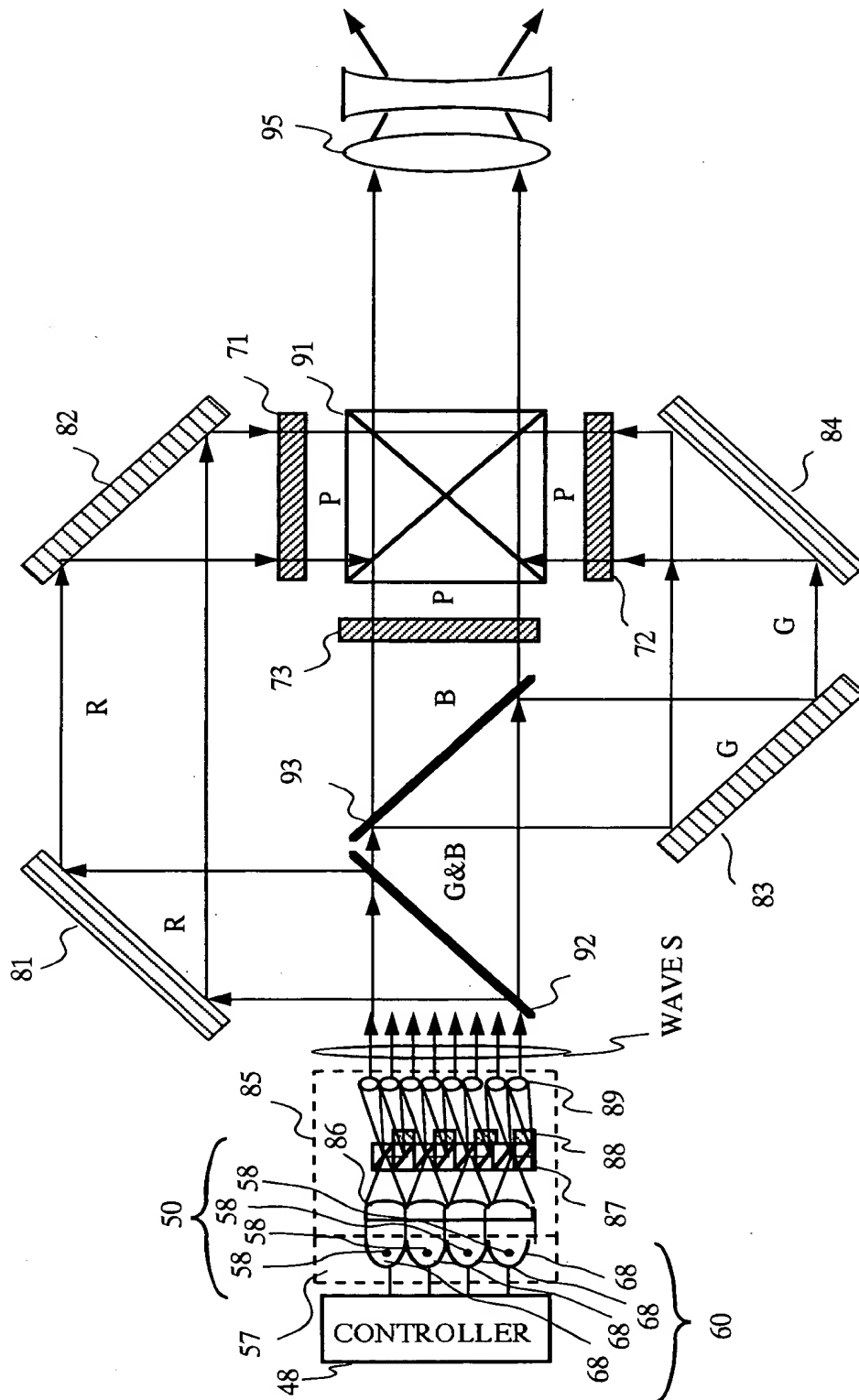


Fig.15



14/66 46
Fig.16

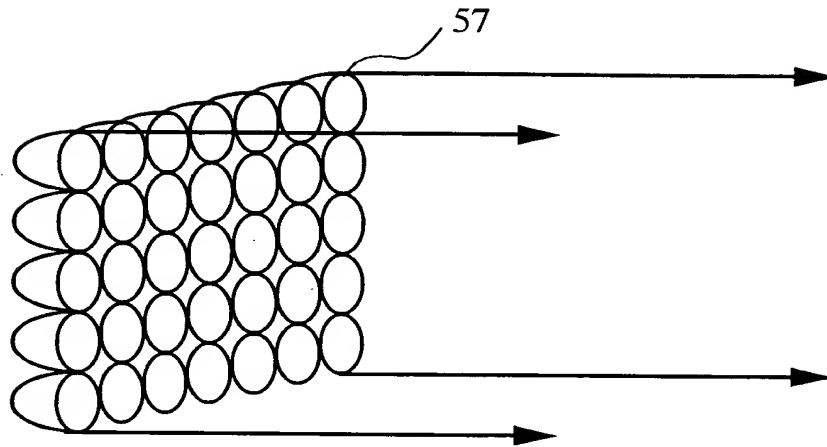
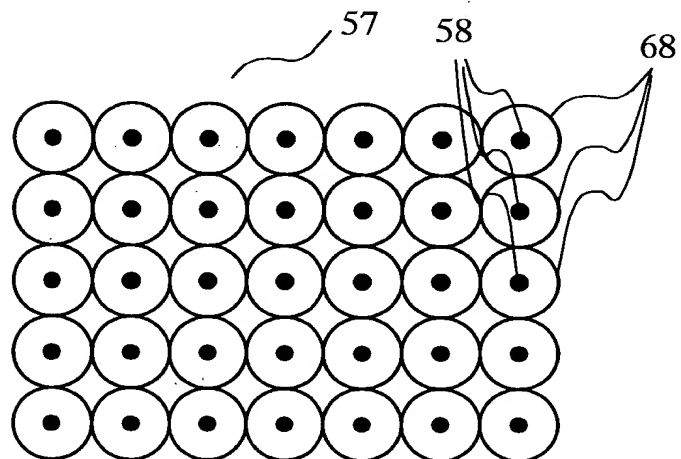


Fig.17



15/66 46
Fig.18

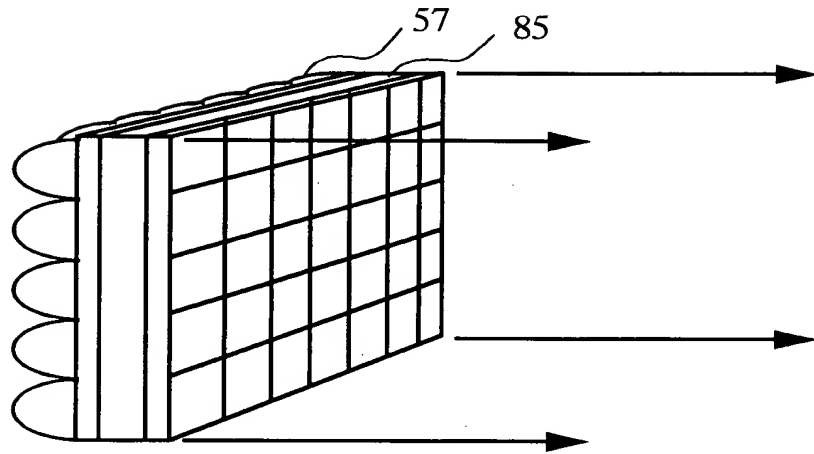


Fig.19

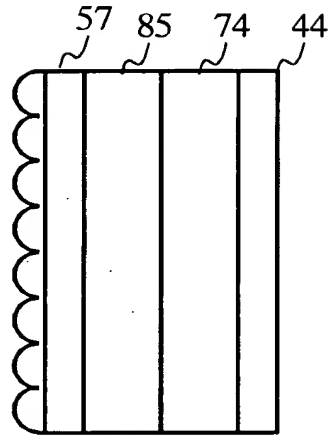
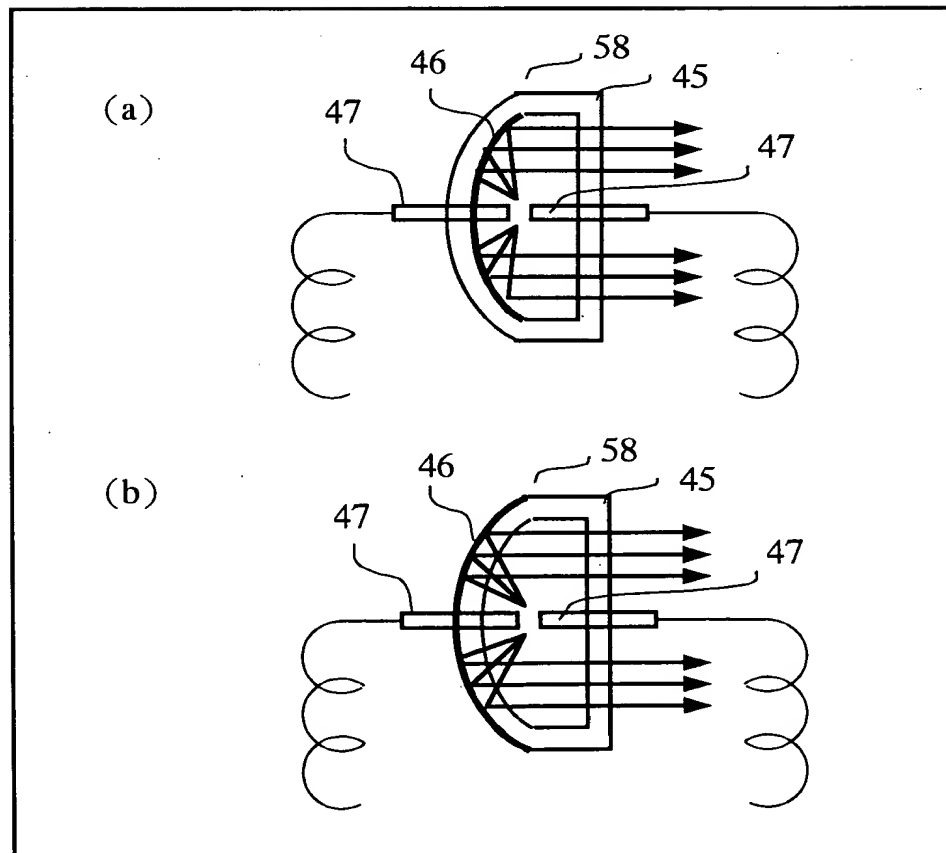


Fig.20



17/66 46
Fig.21

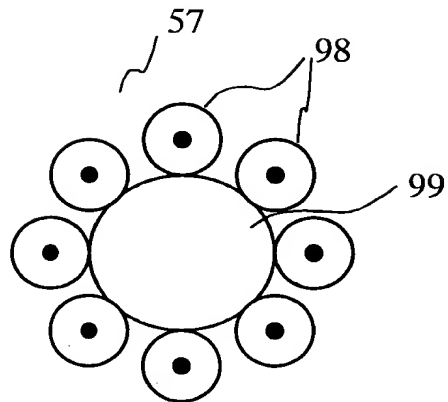


Fig.22

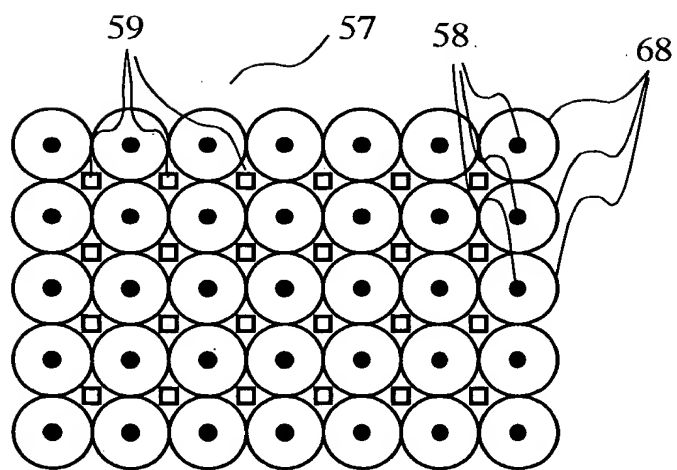
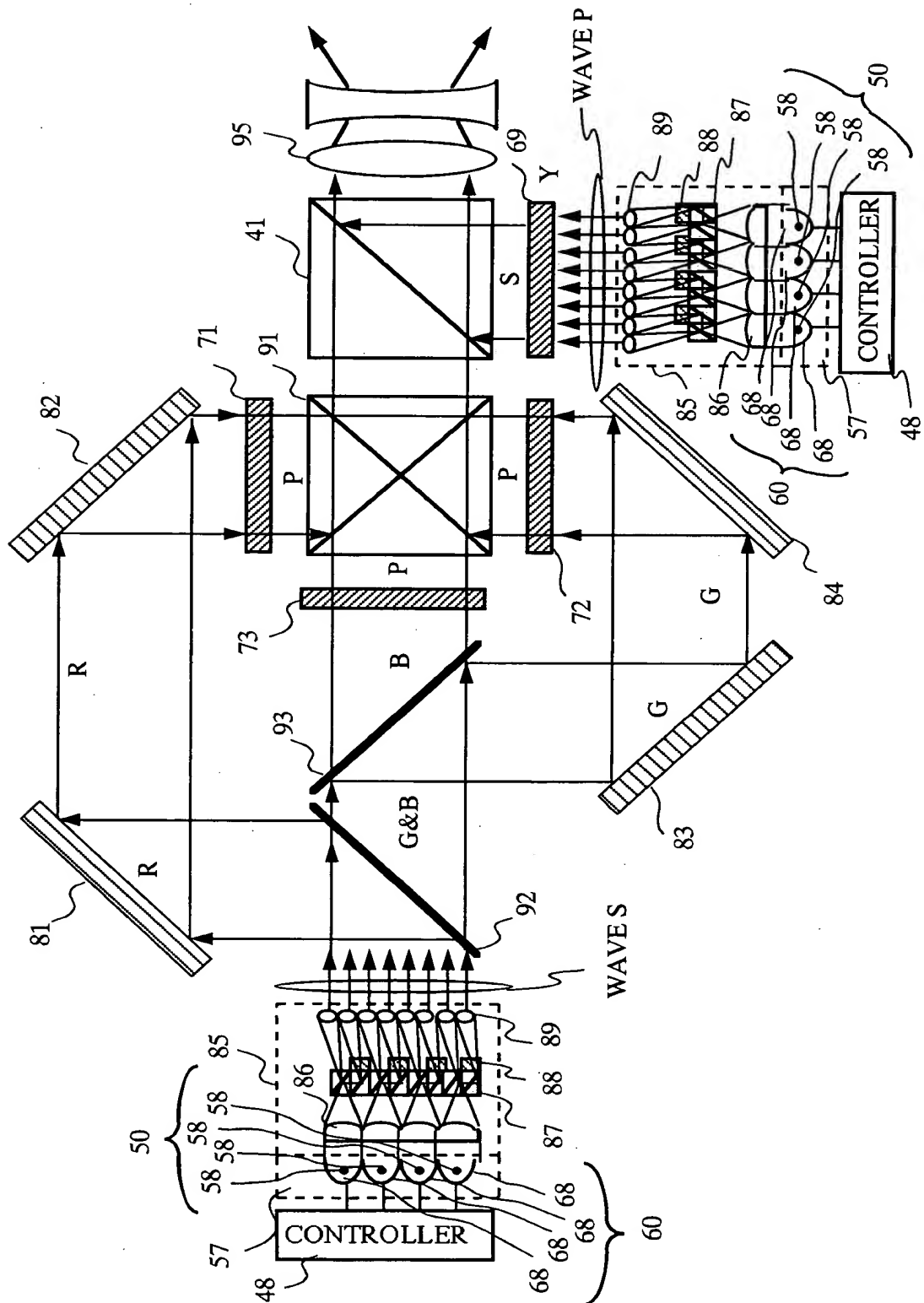


Fig.23



18/66 46

19/66 46

Fig.24

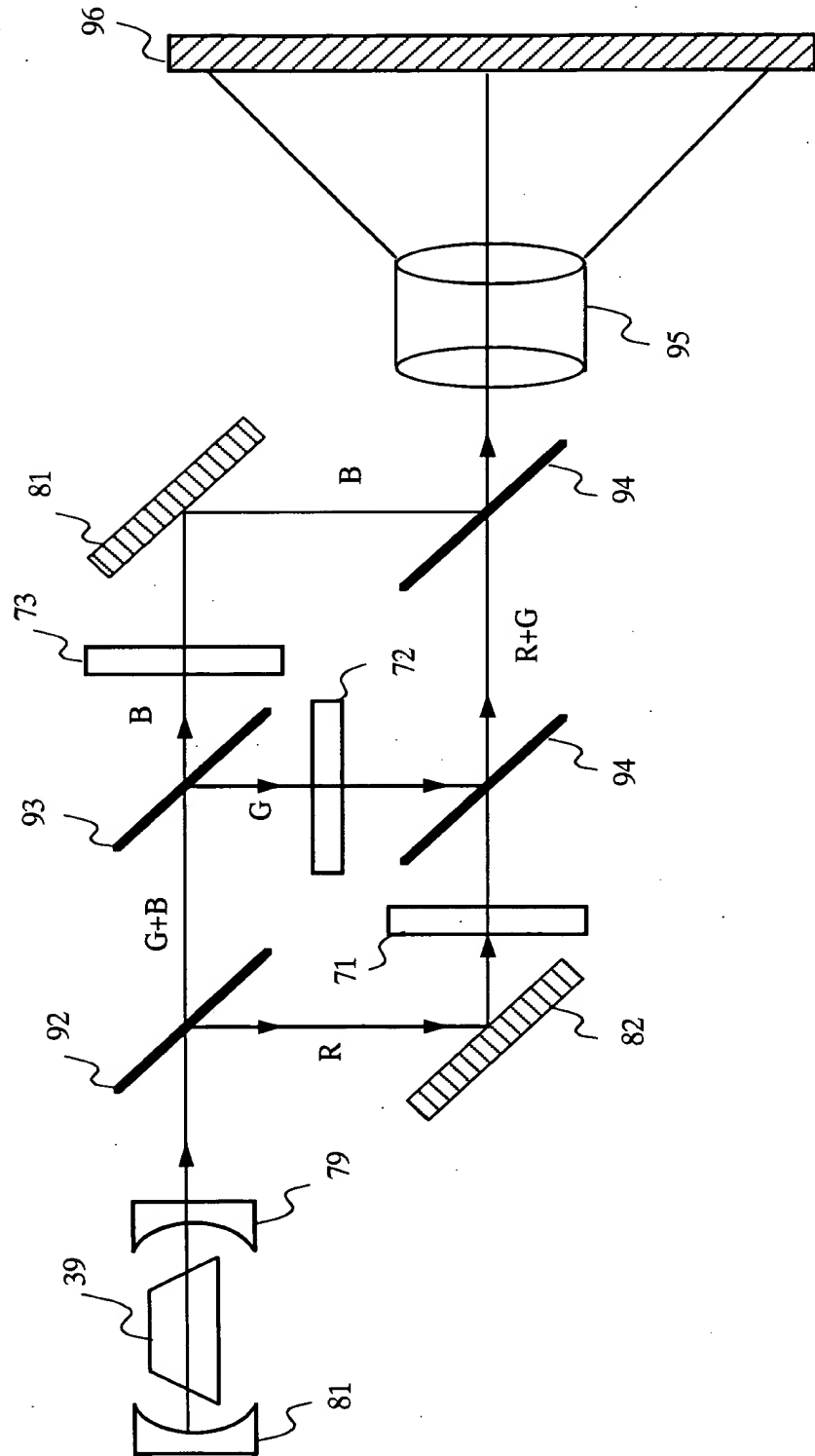


Fig.25

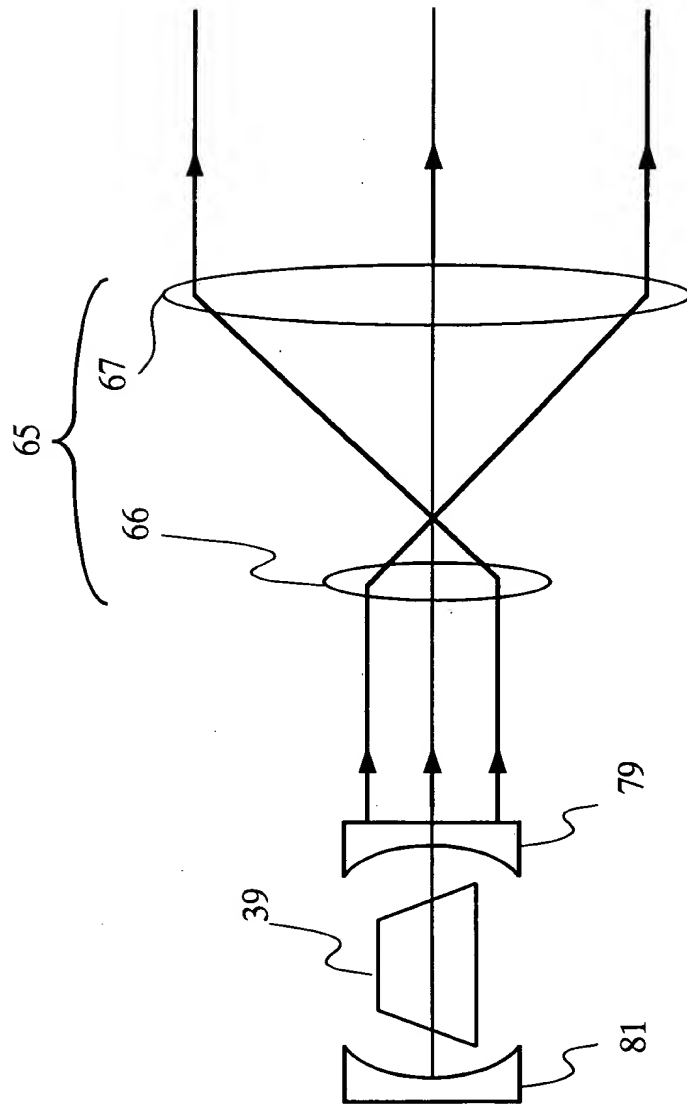


Fig.26

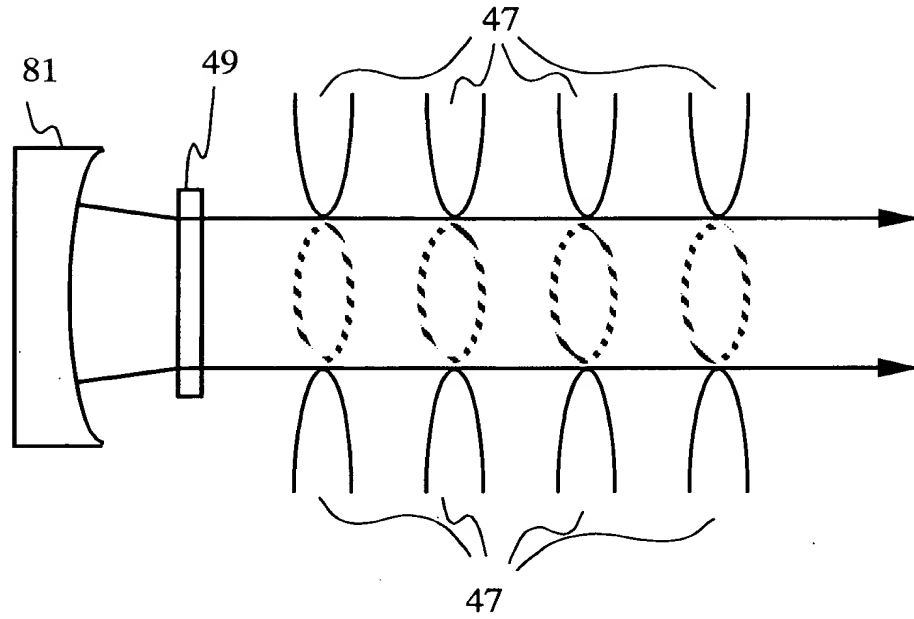


Fig.27

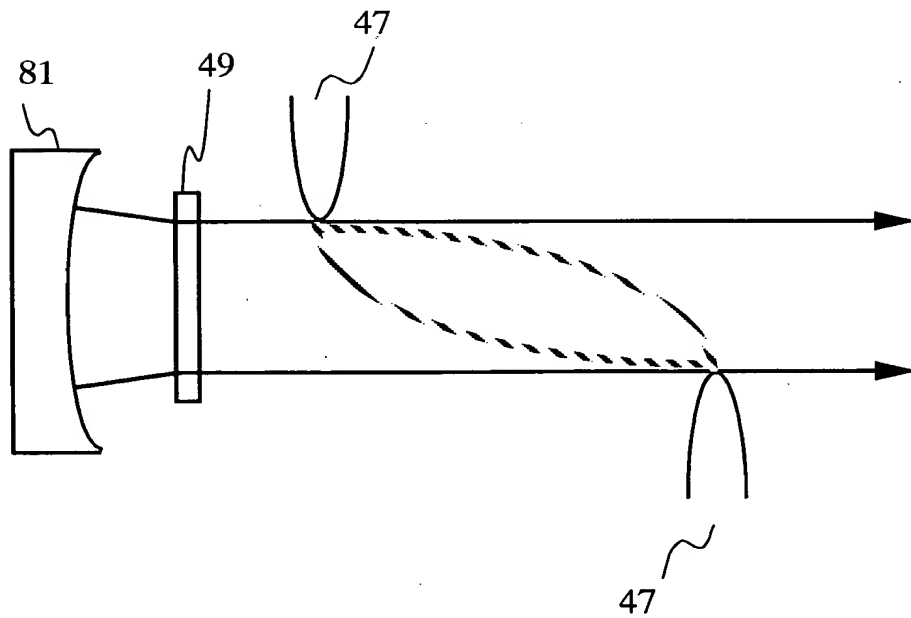
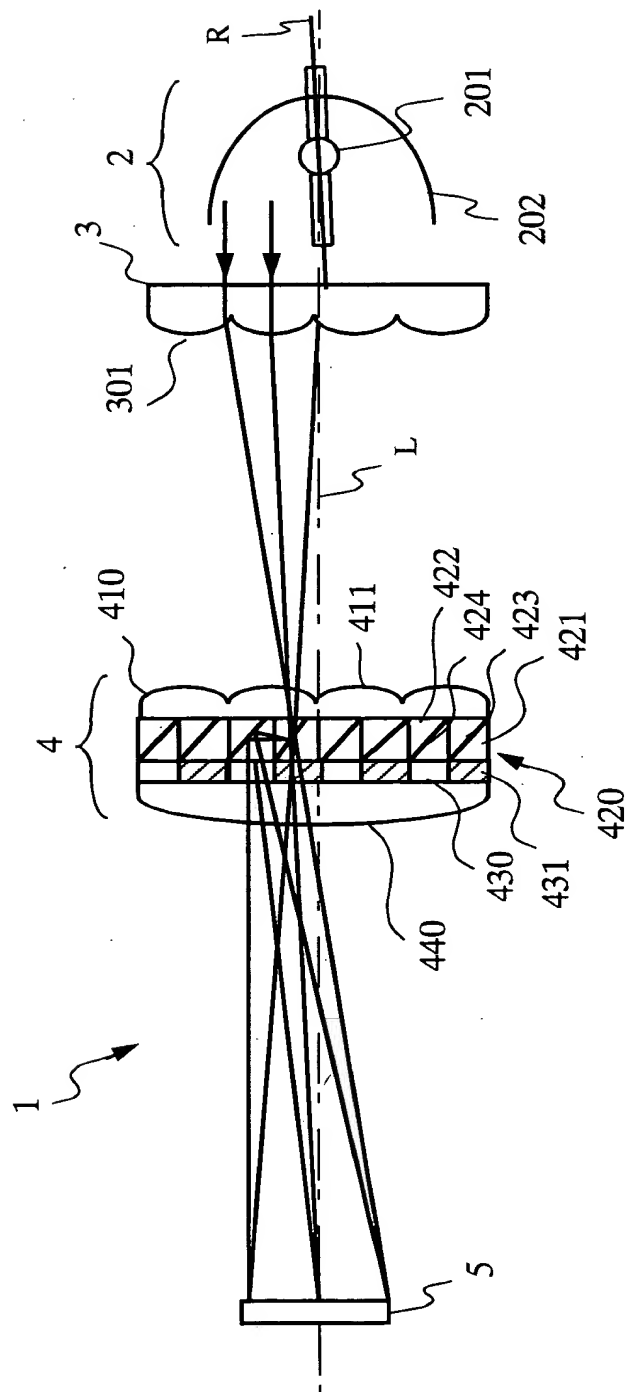


Fig.28



23/66 46

Fig. 29

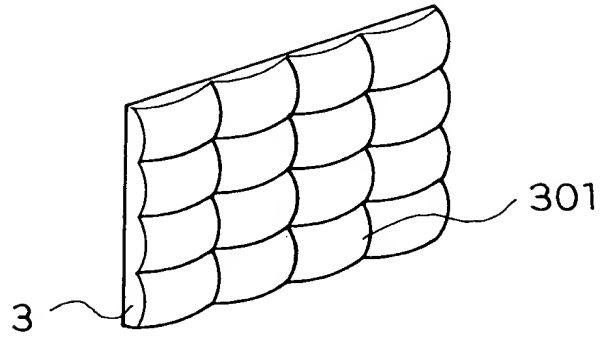
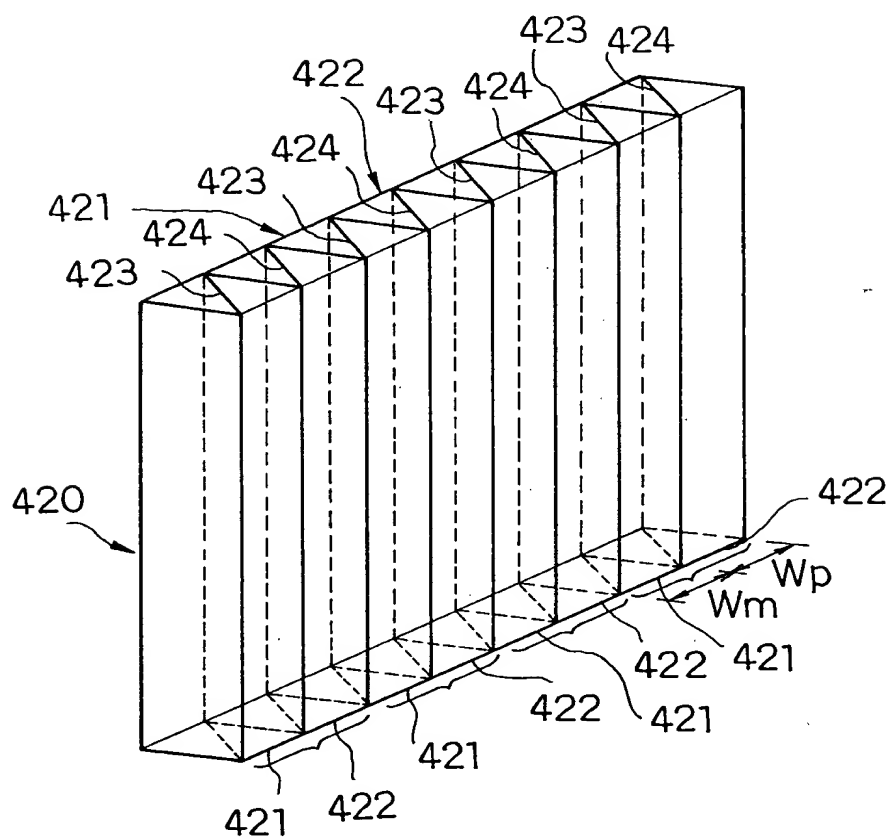


Fig. 30

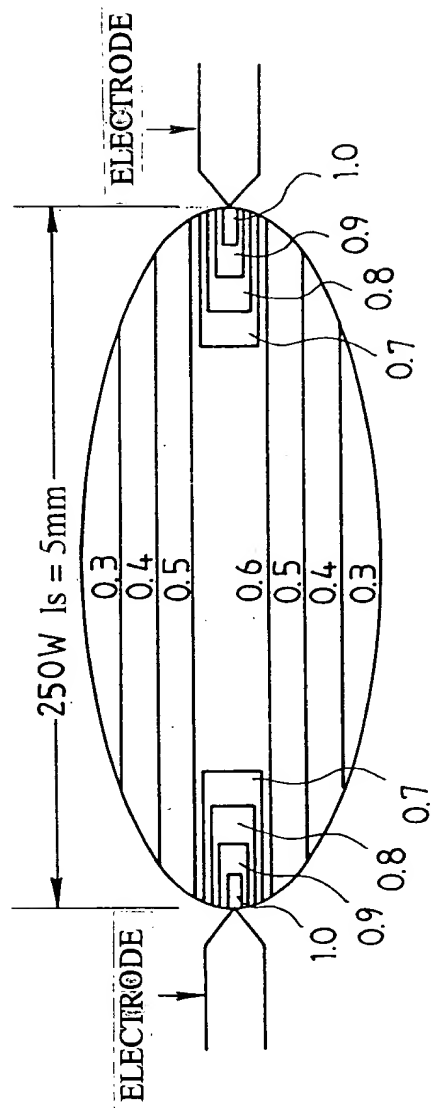


26/66 46

Fig.32

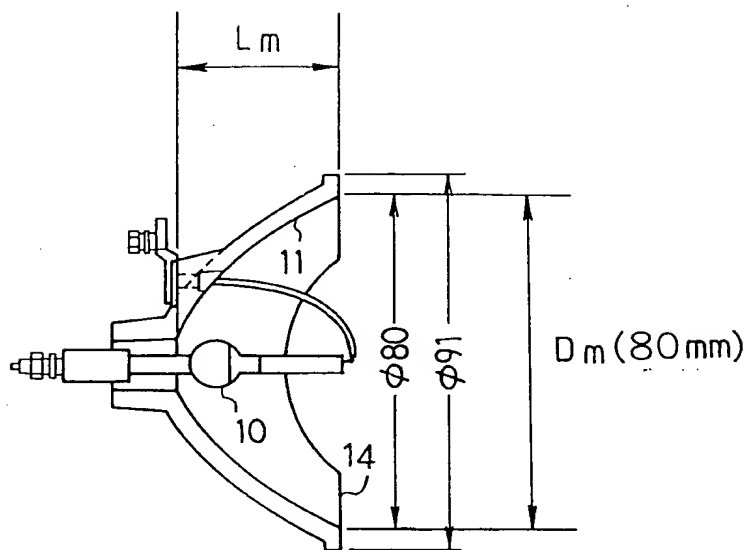
LAMP	METAL HALIDE	XENON	HALOGEN
LUMINOUS EFFICIENCY	80 lm/W	30 lm/W	30 lm/W
COLOR TEMPERATURE	9000 K	6500 K	3000 K
LIFE TIME	2000 H	500 H	100 H

Fig.33



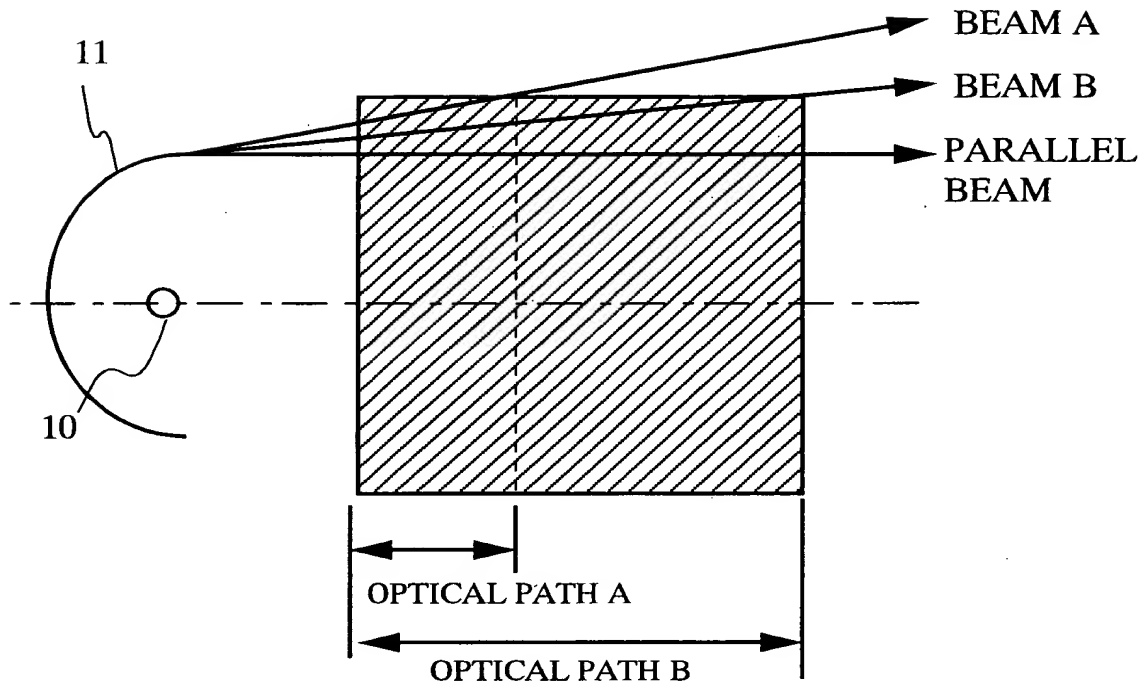
28/66 46

Fig.34



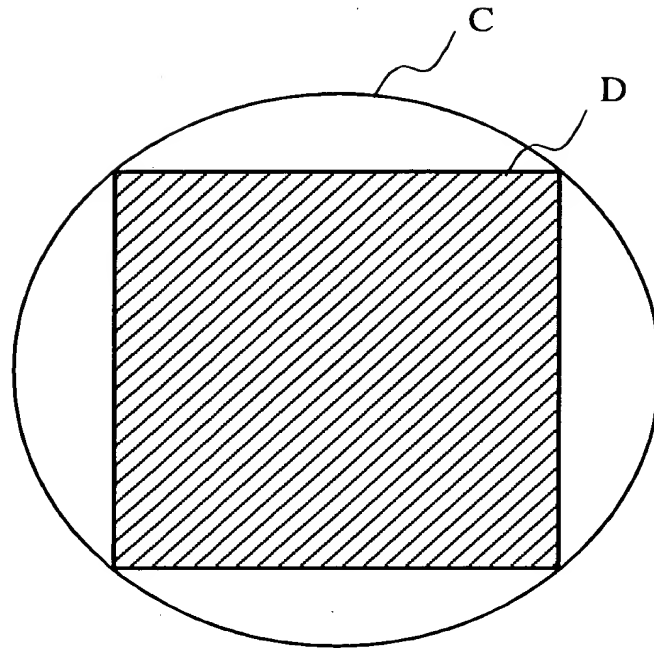
29/66 46

Fig.35



30/66 46

Fig.36



31/6646

Fig.37

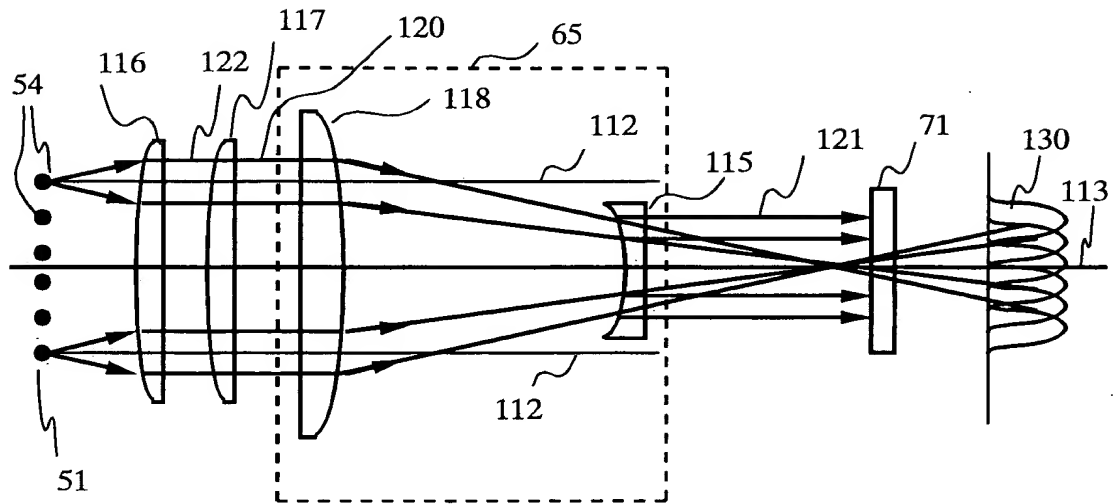


Fig.38

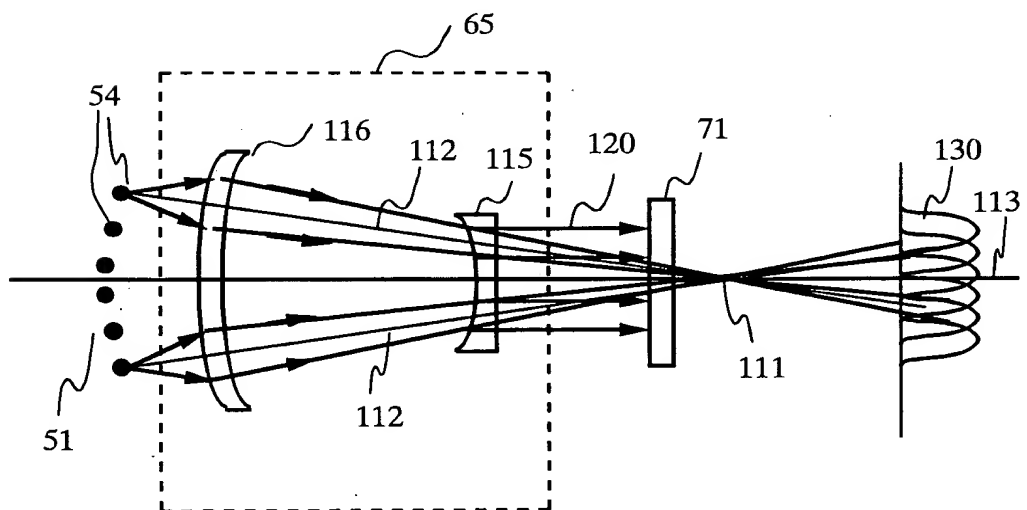


Fig.39

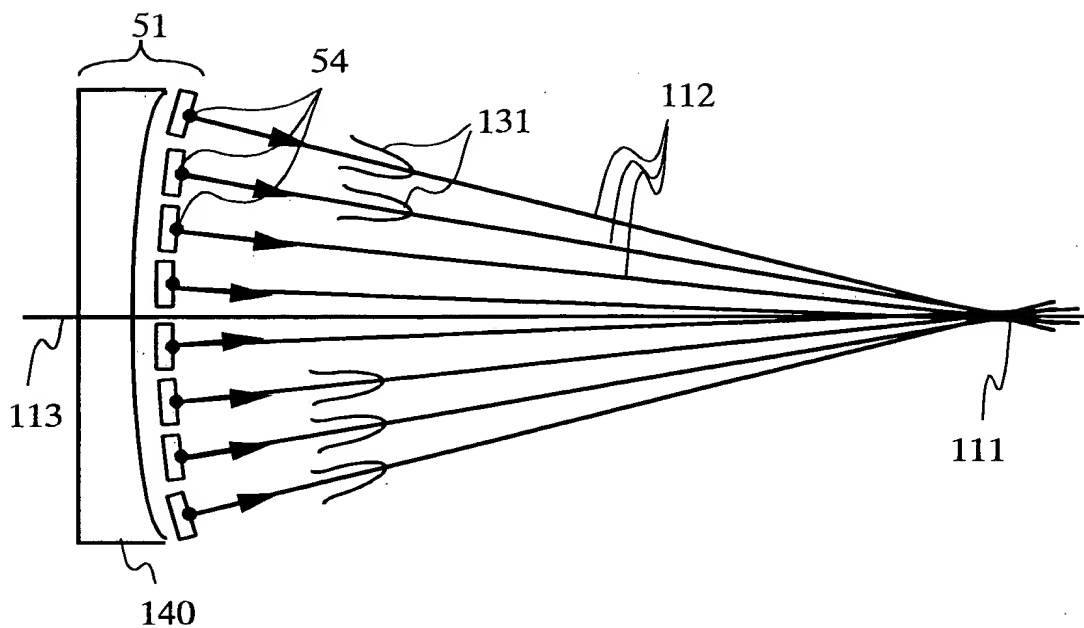


Fig.40

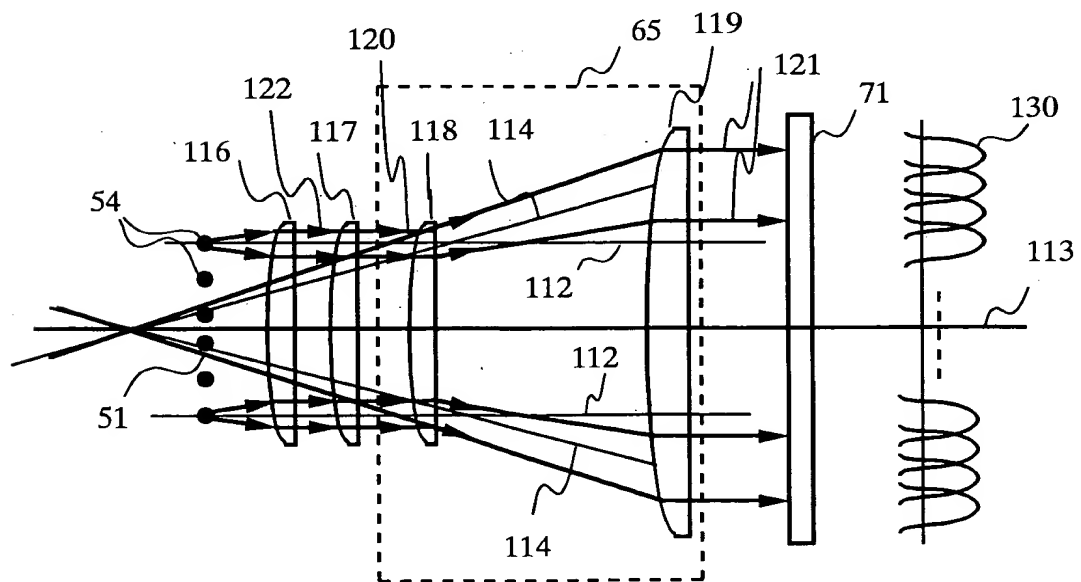


Fig.41

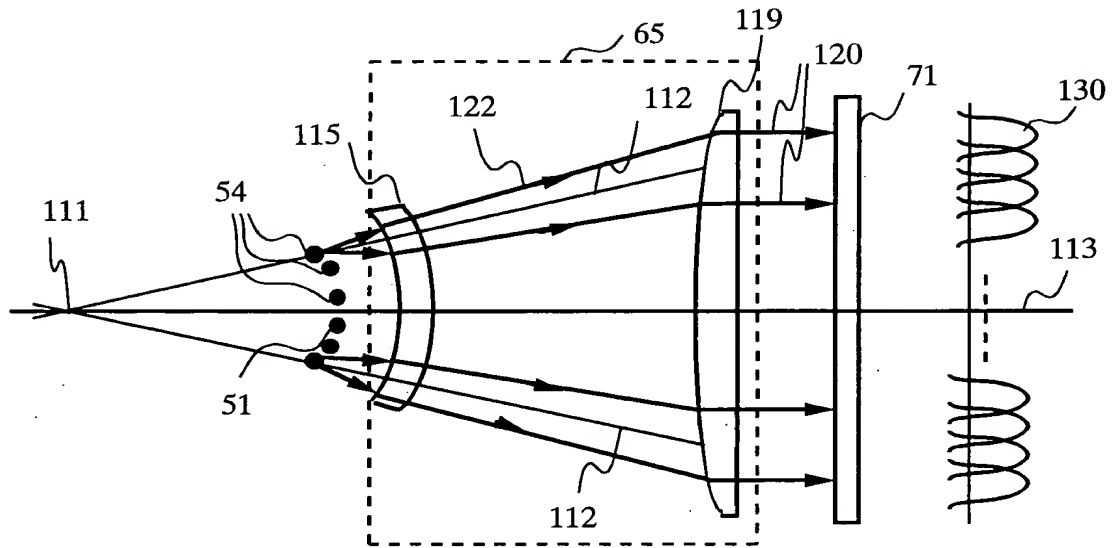


Fig.42

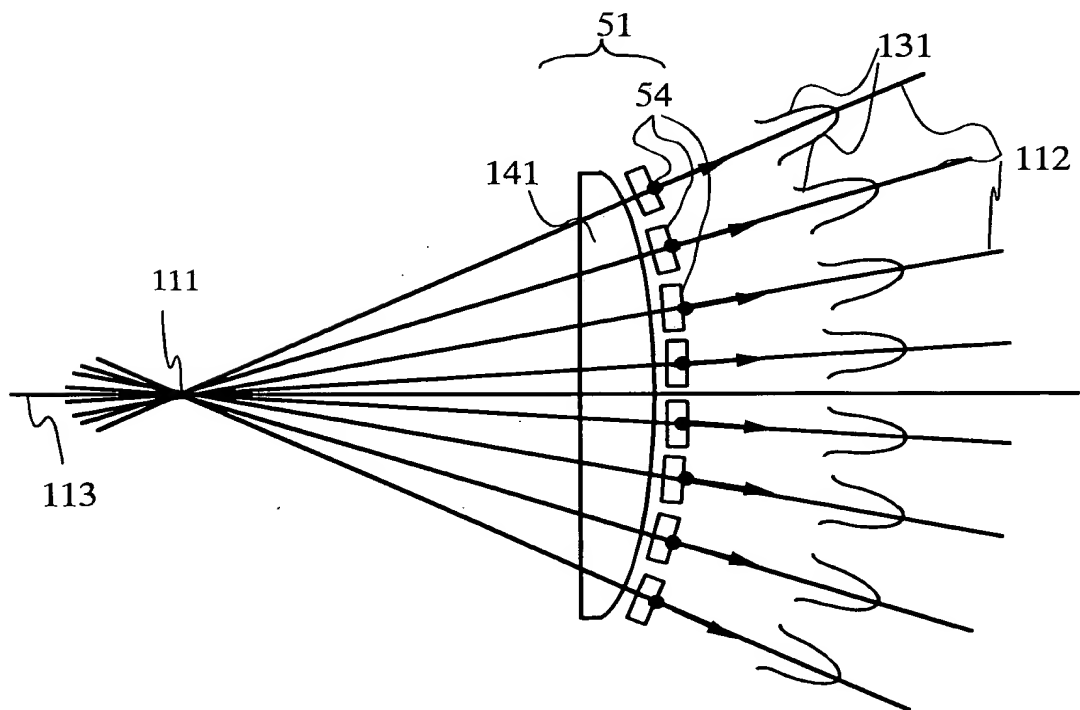


Fig.43

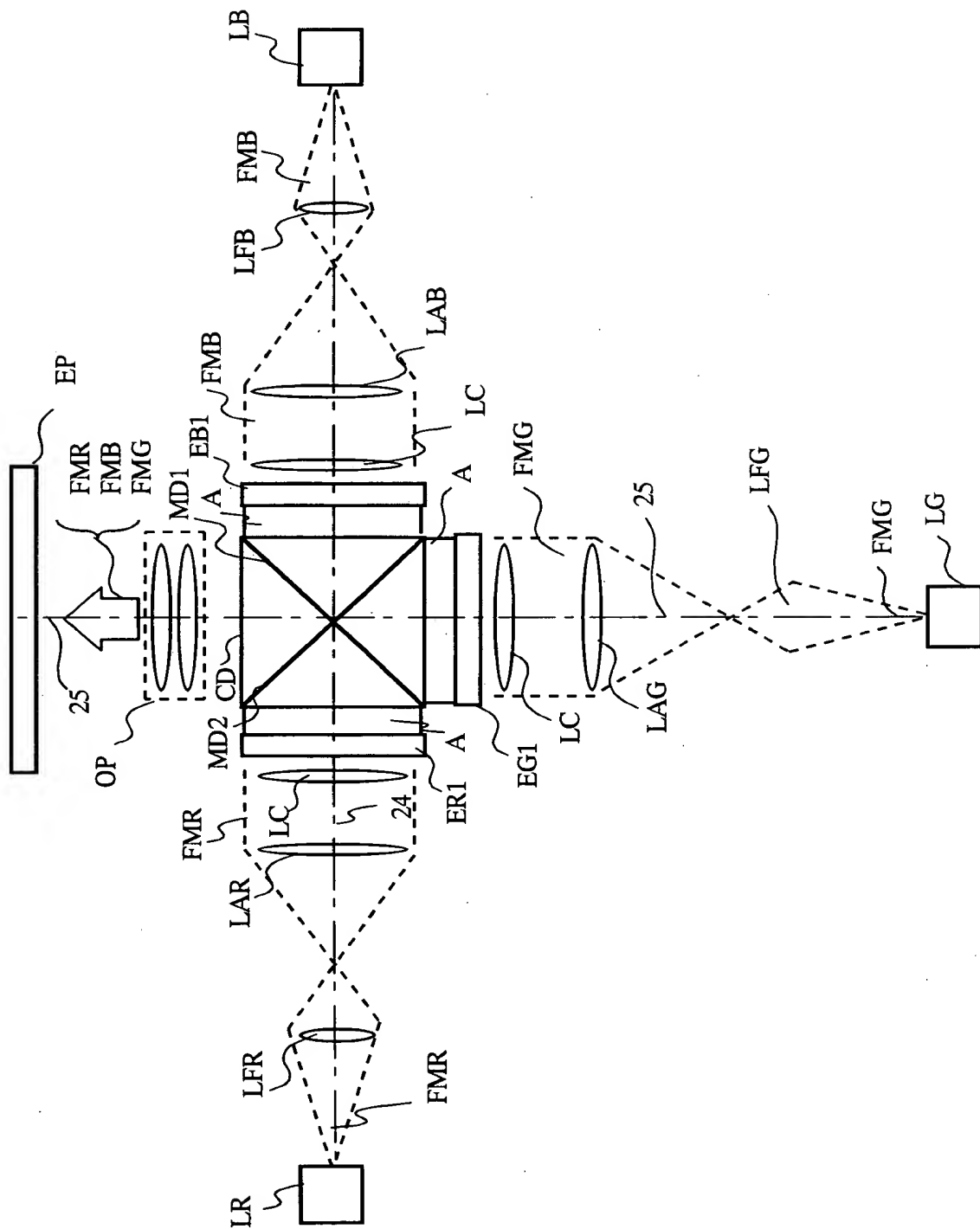


Fig.44

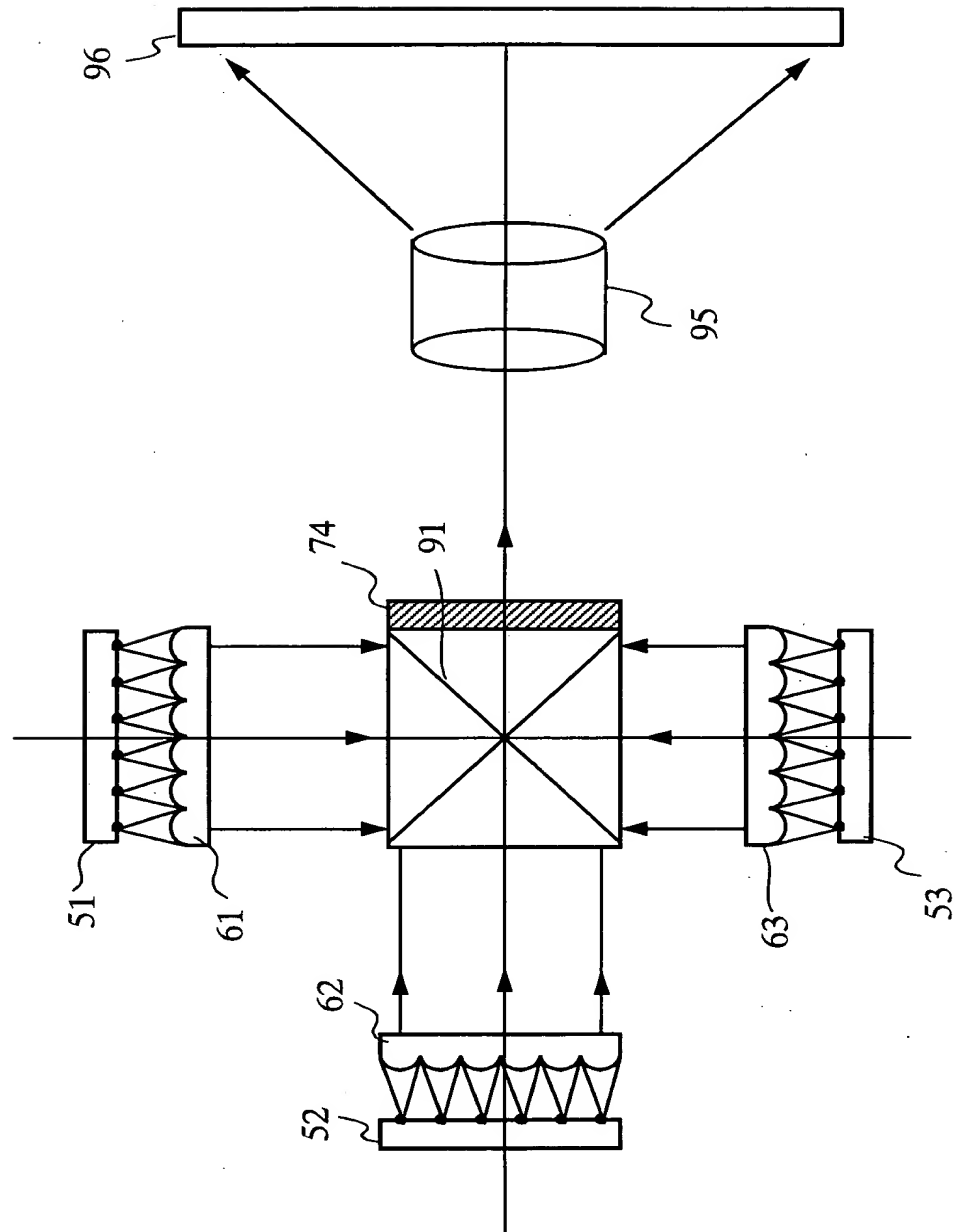


Fig.45

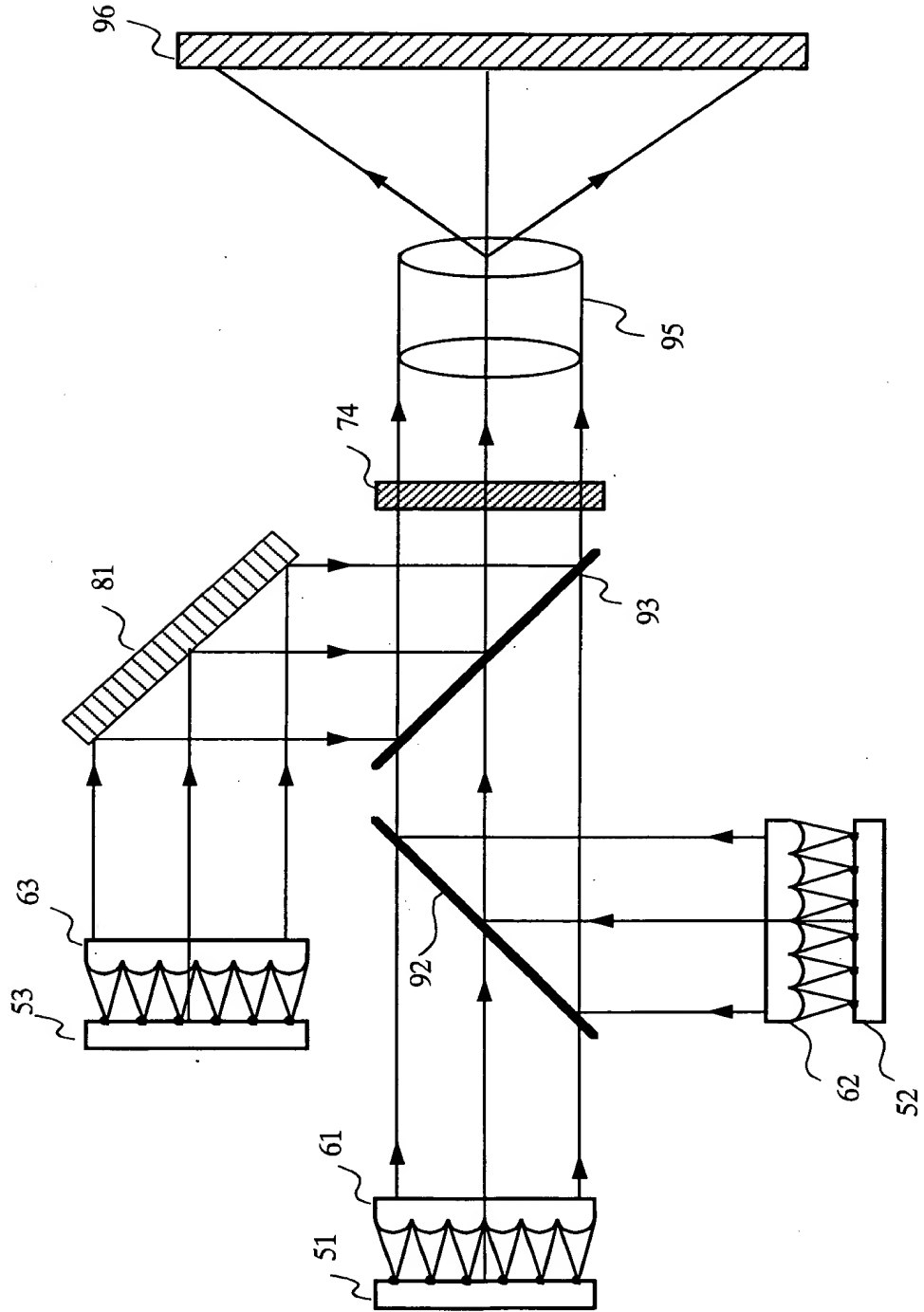


Fig.46

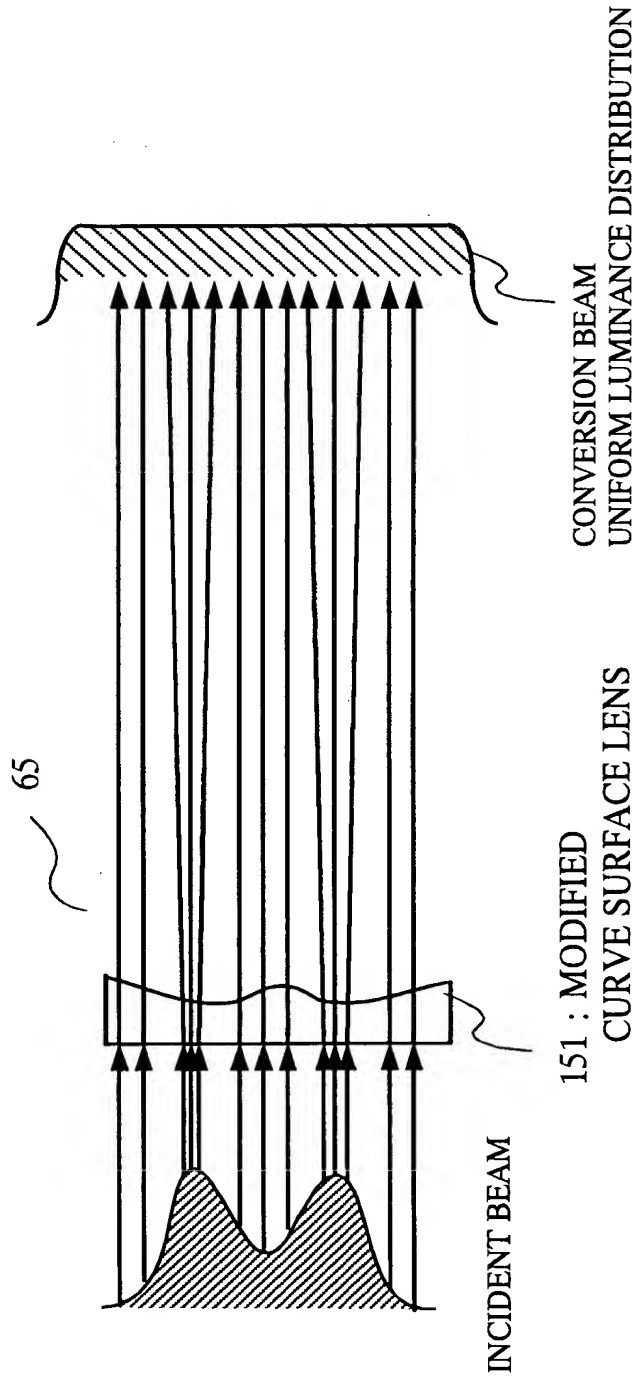
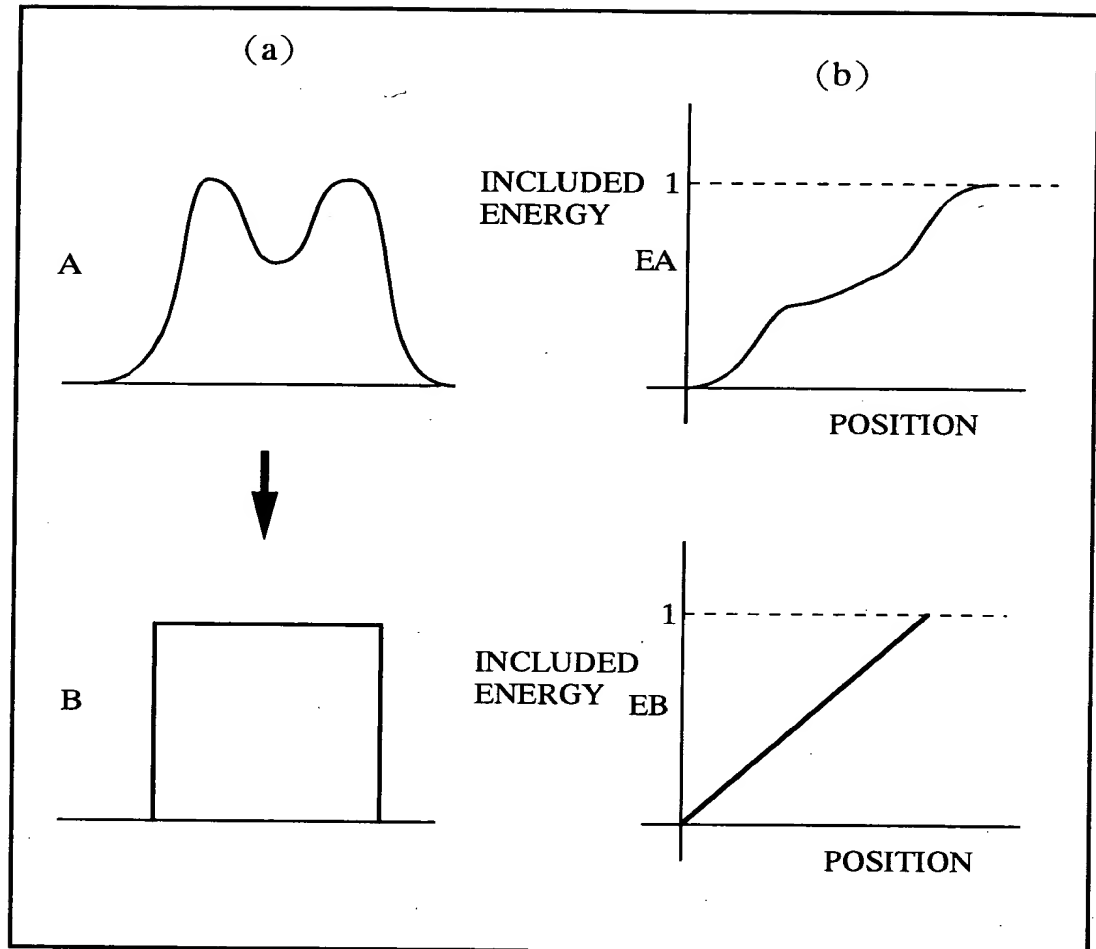


Fig.47



39/66 46

Fig.48

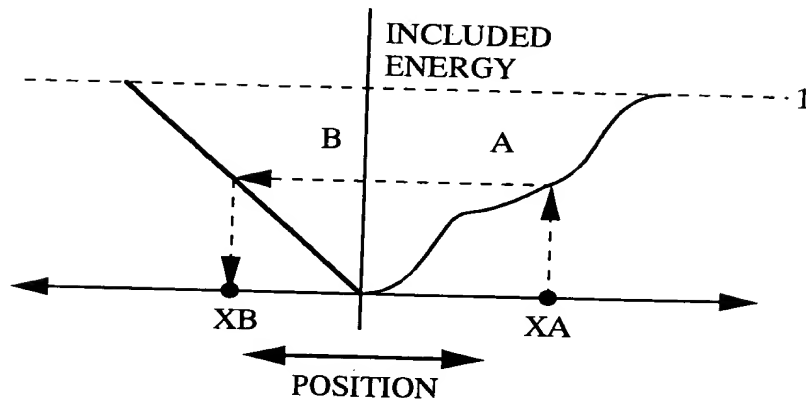
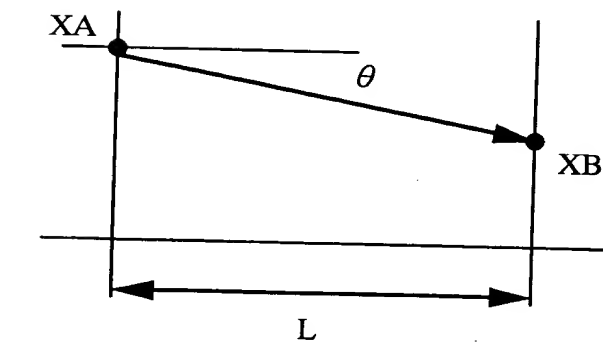
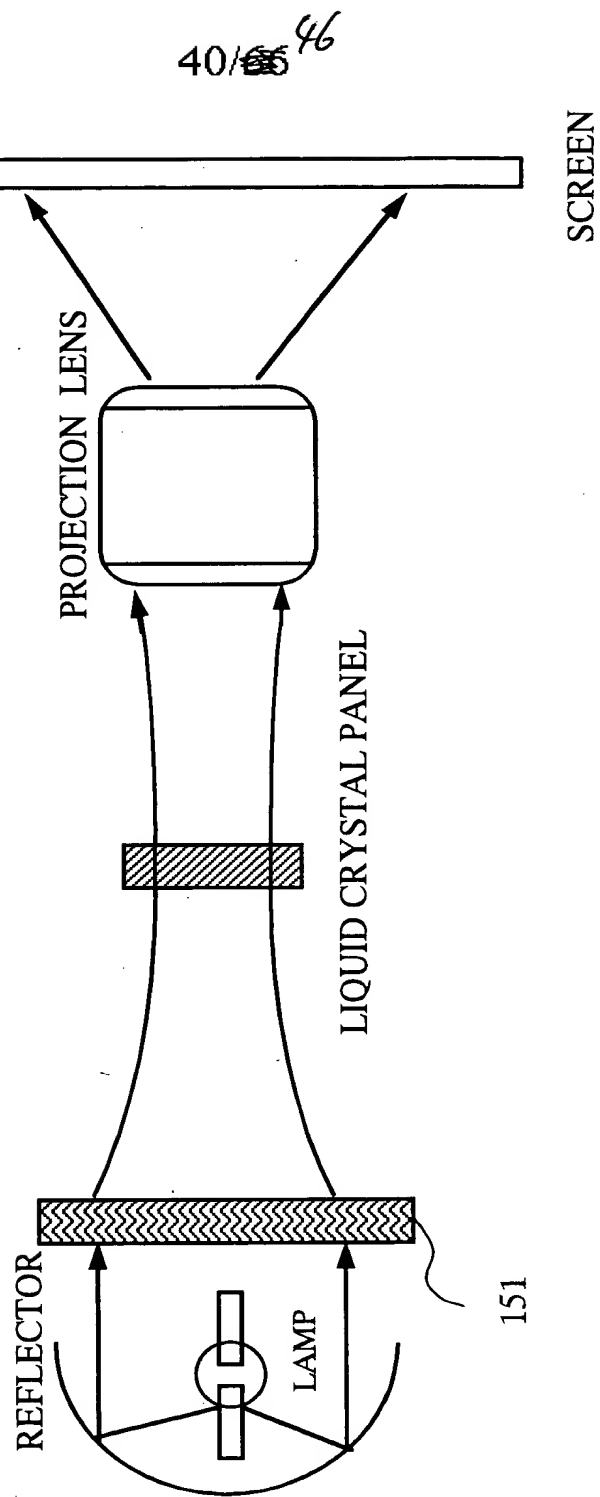


Fig.49



$$\tan \theta = \frac{X_A - X_B}{L} = \frac{X_A - T(X_A)}{L} = \theta(X_A, L)$$

Fig.50



41/66 46

Fig. 51

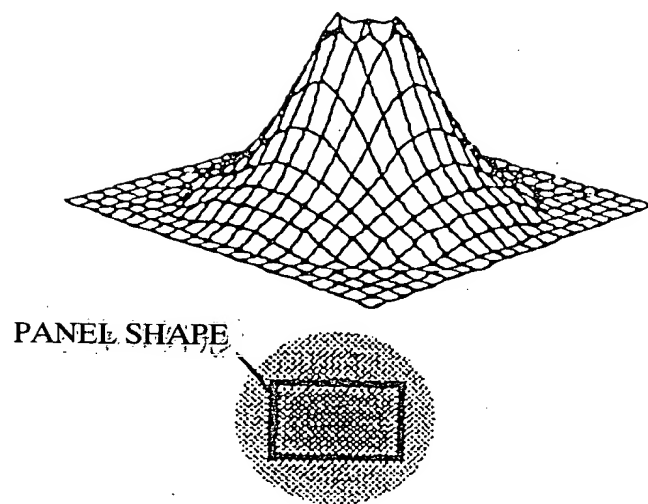
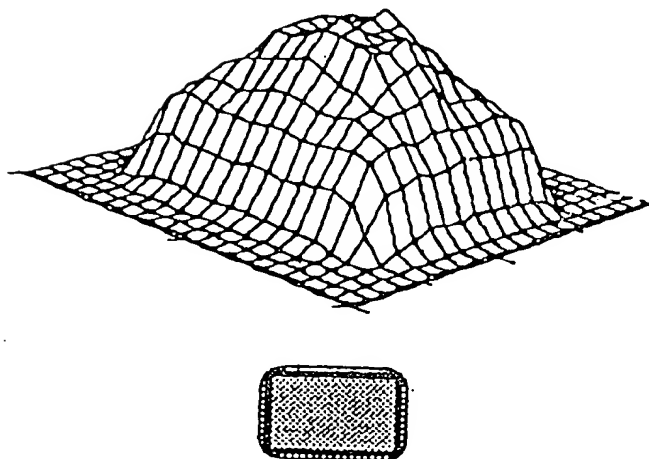


Fig. 52



42/66 46

Fig.53

LAMP 150W、 USING 1.3" COLOR PANEL	REGULAR LENS	MODIFIED CURVE SURFACE LENS
TOTAL LUMINOUS FLUX AMOUNT [lm]	121	261
CENTER ILLUMINANCE[Lux]	410	731
CIRCUMFERENTIAL ILLUMINANCE [Lux]	131	438
ILLUMINANCE RATIO OF CENTER TO CIRCUMFERENCE [%] (UNIFORMITY)	32	60

Fig.54

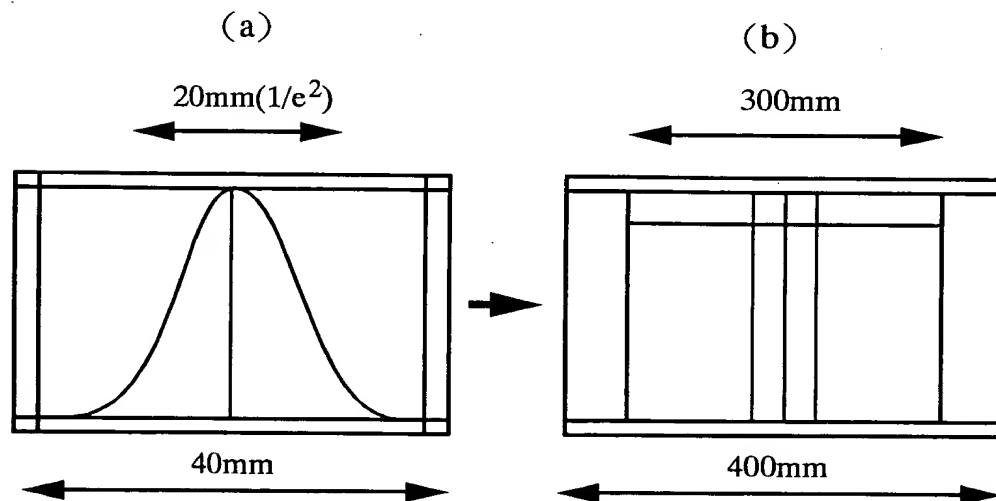


Fig.55

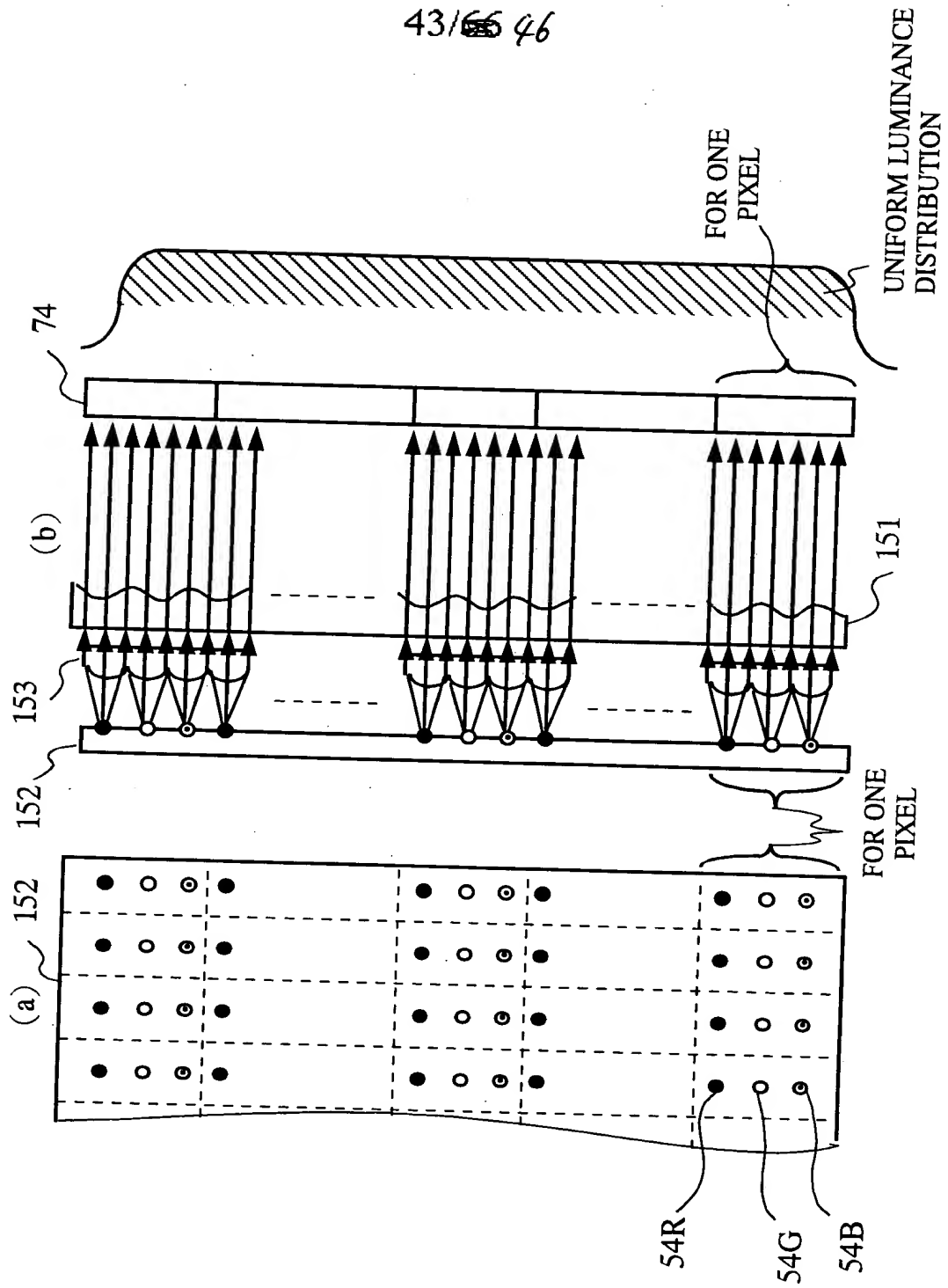


Fig.56

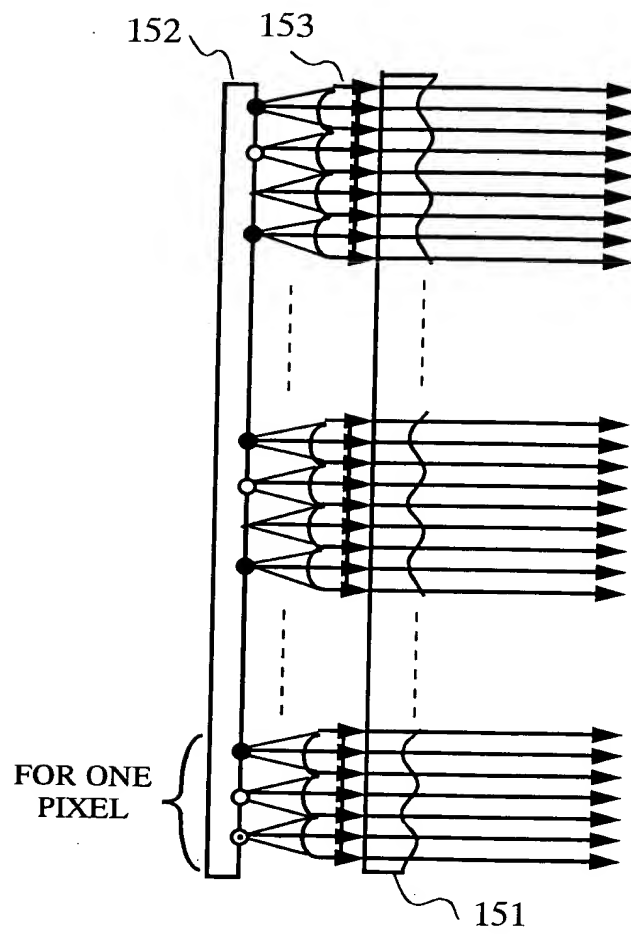
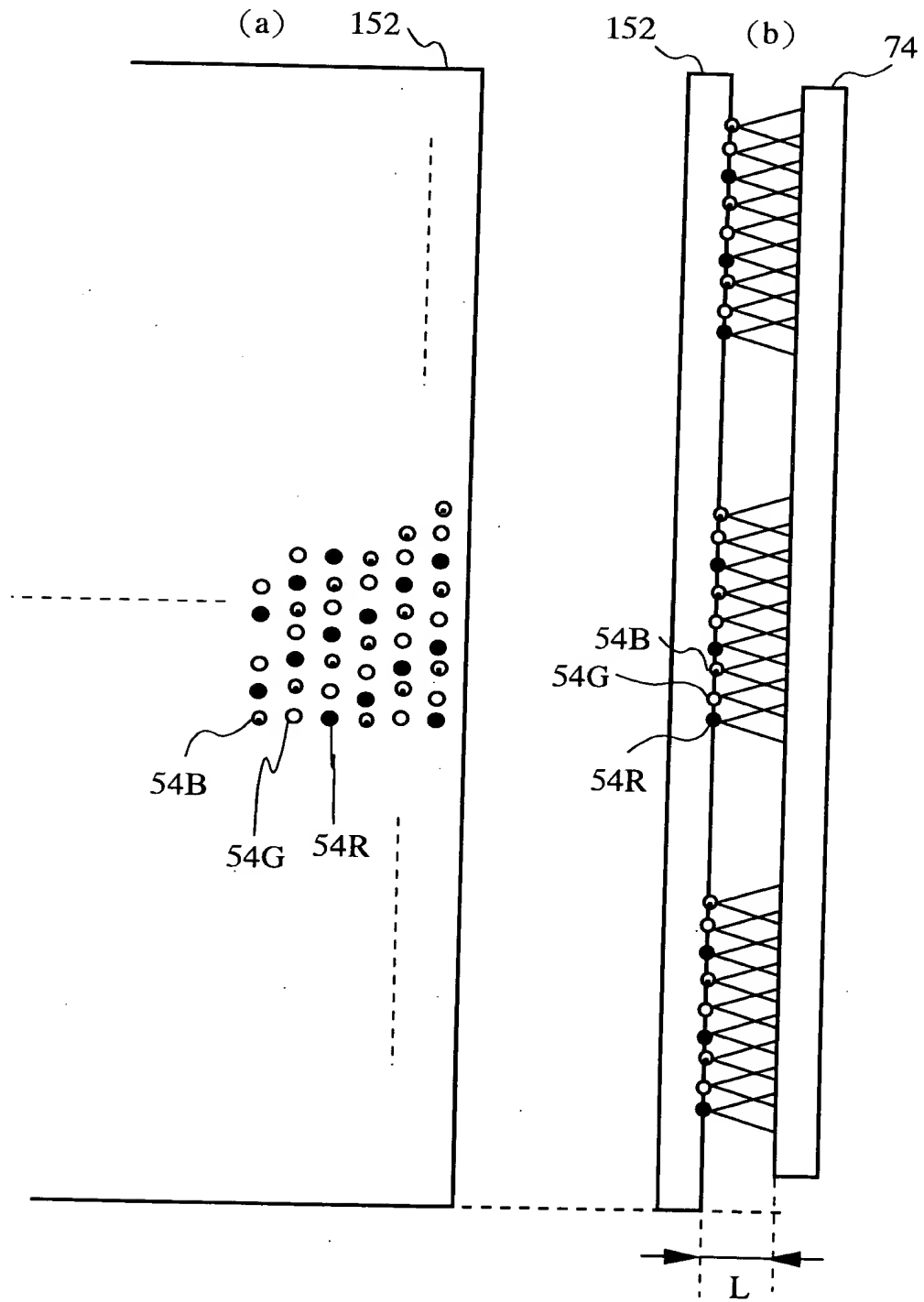


Fig.57



46/66 46

Fig.58

